Our Common Bowl

Global Food Interdependence

IDRC

CANADA

Through support for research, Canada's International Development Research Centre (IDRC) assists scientists in developing countries to identify long-term, workable solutions to pressing development problems. Support is given directly to scientists working in universities, private enterprise, government and non-profit organizations.

Priority is given to research aimed at achieving equitable and sustainable development worldwide. Projects are designed to maximize the use of local materials and to strengthen human and institutional capacity.

Led by the dedication and innovative approach of Third World scientists — often in collaboration with Canadian partners — IDRC-supported research is using science and technology to respond to a wide range of complex issues in the developing world.

IDRC is directed by an international Board of Governors and is funded by the Government of Canada.

© International Development Research Centre 1992
PO Box 8500, Ottawa, Ont., Canada K1G 3H9

IDRC, Ottawa, Ont. CA

Our Common Bowl : Global Food Interdependence. Ottawa, Ont., IDRC, 1992. 64 p. (Searching series / IDRC)

/Food supply/, /food production/, /food shortage/, /interdependence/, /North South relations/, /agricultural productivity/ – /trade liberalization/, /food crops/, /environmental degradation/.

UDC: 338.439 ISBN: 0-88936-650-0

A microfiche edition is available.

Il existe également une édition française de cette publication.

Our Common Bowl
Global Food Interdependence

Contents

Introduction

"Before you finish eating breakfast this morning, you will have depended on half the world. This is the way our universe is structured.... We aren't going to have peace on earth until we recognize this basic fact of the interrelated structure of all reality."

Martin Luther King Jr

It takes but a few seconds to verify his assertion: our lightbulbs use tungsten filaments from Bolivia, we sit on fumiture made from tropical hardwoods, wear clothes manufactured anywhere from the Philippines to Turkey, listen to radios assembled in Taiwan.

With our breakfast we enjoy tastes from all corners of the globe: wheat and milk from Canada, jam from the Balkans, bananas from Costa Rica, grapes from Chile, papayas from Thailand, tea from Bangladesh, coffee from Kenya, sugar from the Dominican Republic.

It is ironic that a great many of our foodstuffs, even what we have come to consider to be basic foods, come to us from elsewhere. Canada, one of the world's major food exporters, is also a large food importer. Some of these imports come from countries that are among the world's poorest, countries that experience recurring food shortages, where undernourishment is chronic.

Few things link people and countries around the world as much as food. Grain produced in North America is distributed worldwide: more than 100 countries depend on these wheat shipments. Canada depends on the income from the sale of this grain and other agricultural

products. In 1990, for example, Canada exported $13 billion worth of animals and animal products, vegetable products, oils, and prepared foodstuffs. Our imports of these products totalled $8.7 billion of which $3.3 billion went for fruit and vegetables.

This trade is far from equal, however. On the one hand, the North produces and exports mainly staple food crops such as cereals and legumes. The South, on the other hand, produces and exports less essential crops, such as coffee and tobacco, that often command high prices on the world market, but this kind of demand can be fickle. In 1986 alone, for instance, the fall in prices of its commodity exports cost Africa $19 billion, more than the amount it received in assistance.

It is also ironic that the crops the North claims as its own are not native to that hemisphere, but were also "imported": wheat and barley from the Middle East, corn from central America, potatoes from the Andes. The importance of these crops to human development is such that maize and potatoes were chosen by the Smithsonian Institution in Washington, D.C., as two of the five "seeds of change" on which it based its largest exhibit.

It is also to the inhabitants of the South that the North owes agriculture. The first great developments in agriculture took place some 10,000 years ago, in a series of river basins, notably the Nile, the Euphrates/Tigris, the Ganges/Brahmaputra, and the Yangtze. The first essential step occurred when our ancestors concentrated on those wild grasses that promised to yield the most food.

Since then, we have dug up a large part of our planet, one and a half billion hectares in all. The most productive areas to date have been in the temperate zone where soils are naturally fertile: one hectare of naturally rich soil in Britain or the US, for instance, can yield as much as 10 hectares in Bolivia or Zambia.

Globally, harvests were adequate until some 50 years ago when the growth of both population and demand forced us to concentrate on a handful of high-yielding crop varieties to supply us with the bulk of our dietary needs. In so doing, we sowed the seeds of global food dependence and interdependence. As this publication shows, that interdependence will continue to grow.

Notwithstanding advances for certain crops, such as wheat and rice in favourable environments, there are many areas for which there are few proven technologies to increase output or reduce costs in a manner that is sustainable over the long term. The problem of access to food remains fundamental for countless poor, even in areas that have benefited from new technologies and production methods, even in the rich North. As populations relentlessly grow, particularly in areas that are already food deficient, the problem of food access is likely to reach alarming proportions.

Helping to solve these problems is one of the mandates of the International Development Research Centre (IDRC). Many of the research and development projects cited in this report were supported, at least in part, by IDRC.

This publication examines the issue of food: where it came from, where it is now, and where it is likely to come from in the future. It ponders solutions to the equation posed by the Resource Clock in the lobby of IDRC's headquarters: the top line relentlessly counts up each new birth while the bottom counts down each lost hectare of productive land on which to grow food to sustain them.

This booklet also shows that, although they are intertwined, there is a dichotomy between the world hunger problem and the world food problem. More food may be essential to deal with hunger, but the alleviation of poverty that prevents individuals, communities, and countries from acquiring available food is no less important. Solving those problems will require concerted action in both North and South.

The Global Pantry

The world's pantry is far from bare. But each year there are more people in the world who do not get enough to eat. According to the United Nations Development Programme (UNDP), some 800 million people go to bed hungry every night. In 1991, one in three children — about 180 million — were severely underweight, putting their healthy development and lives at risk. These numbers are likely to keep on growing.

The causes of hunger are many and complex: rapid population growth, uneven distribution of food, inadequate domestic agricultural production, and natural disasters, among others. But as the UNDP's Human Development Report 1991 stresses, it is due above all to poverty, to a lack of financial resources to buy the needed food: countries and families that can afford it purchase all the food they need.

The problem, simply stated, is that many people do not have enough to eat, although there is food enough for all. We have failed, not to produce food, but to give people the opportunity and means of securing it. This section examines how food is distributed around the globe and some of the ways in which the South is denied access to the world's storehouse.

Half-empty, half-full

Between 1950 and 1984, world cereal production steadily outstripped population growth: between 1965 and 1985, cereal production increased from around 700 million tons to more than 1,800 million tons, an increase of 65% or about 2.7% annually. Production of tubers also increased by 24%.

Some of this gain was realized by bringing new lands into production. Between the mid-60s and mid-80s, an additional one percent per year of the world's forests was cleared for pastures and cropland: only Europe reversed the trend. New lands have been opened up on which to grow staple crops: between 1950 and 1980, for instance, grain growing areas, which now occupy 70% of all croplands, expanded by 25%. Half of that expansion was in the USSR where "virgin lands" were brought under the plow. The rest was made up of the recultivation of 20 million idle hectares in the US and an extension of arable lands in Argentina, Brazil, Nigeria, and other developing countries.

More of the increase, however, was due to higher yields per hectare as a result of the massive use of fertilizers and pesticides, extensive

development of irrigation, and the introduction of high-yielding, fast-maturing varieties, particularly in developing countries.

It was also the direct result of heavy global investment in agricultural research that yielded the "Green Revolution" in wheat and rice, led by multidonor investments in research at the International Wheat and Maize Research Center (CIMMYT) in Mexico and the International Rice Research Institute (IRRI) in the Philippines.

These increases in world food production may have staved off starvation in Asia, but they were far from equitably spread: in the centrally planned economies of Asia (China, Kampuchea, Mongolia, North Korea, and Vietnam), per capita food production in 1981–84 was 135% what it had been in 1961–64. In Africa, it was 88%.

This growth of production in some areas, and of demand everywhere, altered the pattern of world trade in foods, particularly cereals. Before World War II, North America exported barely 5 million tons of foodgrains a year. In the 1980s, it exported nearly 120 million tons. Most of those exports were to the former USSR, Asia, and Africa. Three countries — China, Japan, and the USSR — took half the world exports in the early 1980s. Much of the rest went to relatively wealthy developing countries, such as Middle Eastern oil exporters.

The geography of hunger

Drawing a map of the world's croplands would reveal that, despite large areas of potentially arable lands in the South, food growing is concentrated in the northern hemisphere and in Asia. If our map were proportional to each region's ability to feed its population, North America, Japan, and Oceania would dominate the globe; by diverting grain and root crops from animal feed to human food — or, better yet, by planting the area devoted to these crops to higher value crops for human nutrition — these wealthy countries could support three times their current populations. Western Europe also boasts well-stocked larders, enough to feed close to 300 million more people. In theory, Eastern Europe and the USSR could likewise comfortably feed their populations if all cereals were consumed by humans. Yet they depend on massive grain imports.

Although it makes up just 7% of the world's arable land, China grows enough food to feed 22% of the world's population — no mean feat. Elsewhere, the situation is not as rosy. Latin America, for example, has a low production of both cereals and root crops and barely manages to feed itself. Because land is concentrated in the hands of a small number of wealthy landowners, much of the arable land is underutilized. Asia, despite a high rate of food production, cannot keep pace with its burgeoning population and has stretched its land beyond its limits. Finally, Africa is attempting to feed 11% of the world's population on 7% of its staple crop production. It is a region of the world that has grown steadily hungrier since 1970.

There is a sharp divide between glut in the North and hunger in the South. An equally wide gap also occurs within countries of the Third World where the richest 20% of the population may be 10–20 times more affluent than the bottom 20%. There are several reasons for this: social inequalities; low purchasing power for some sectors of the population; and storage and transportation problems. Industrialized countries are not immune from these problems as recent shortages of staples in cities of the former USSR testify.

It must be remembered that national food and nutrition statistics can be misleading: people go hungry even in food-rich countries. Whether you live in Calcutta or Vancouver, the sad truth is that your financial situation will determine whether you eat adequately or not.

According to the World Bank, dietary deficiency represents only a small fraction of the food supply in most countries — typically from 5 to 10% of the national food supply. But increasing food supplies proportionately would not necessarily eliminate malnutrition because it would not necessarily improve the incomes and purchasing power of the poor. In many countries, the national food supply is sufficient or could easily be expanded to feed the entire population adequately. Studies carried out for the International Labour Organization, for instance, show that famines in Ethiopia and Bangladesh in the 1970s did not result from a shortage of food, but from an unequal distribution of food. In Ethiopia, drought caused crop failures in Wollo province, The impoverished farmers could, therefore, not afford to buy the food that was readily available in other parts of the country. During the Bangladesh famine of 1974, one million people died even though the country's food output that year was higher than in the previous 4 years.

Other low-income countries, particularly in Africa, do have a national supply problem and require large increases in food imports, imports they can scarcely afford. In Ethiopia, for instance, the cost of the required imports would be about equal to its export earnings.

World agricultural patterns

Crop production per hectare depends largely on the agricultural system employed. North America, Western and Eastern Europe, Australia, and New Zealand — as well as some areas in developing countries — practice industrial agriculture; it is capital- and input intensive, usually large scale and highly productive. The 2% of the American population who engage in agriculture, for instance, feed their fellow citizens and provide more than half of all the agricultural products on international markets; that is, 15% of the world's wheat, 21% of the oats, 36% of sorghum, and 46% of maize on 11% of the world's croplands. But this staggering production comes at a price. Estimates of soil loss through erosion are in the order of some 5 billion tonnes of topsoil a year. Close to 80 million hectares of croplands have been rendered unproductive. Moreover, the application of vast quantities of pesticides and an average of 93 kilograms per hectare of synthetic fertilizers

Grain: Food or feed?

More than one-third of the world's grain production — mostly maize — feeds livestock, not people. In industrialized countries, the figure can be much higher.

Common wisdom would have it that this grain is a reserve that should be diverted to meet human needs. According to the World Bank, however, this stock of grains is at best only a limited reserve. About 80% of feedgrain consists of coarse grains, mostly maize. Only about 15% is wheat, and a lot of that is unfit for human consumption.

Coarse grains are an important food source in some parts of the world, such as Africa and Mexico, but wheat is the staple food throughout North America, Europe, North Africa, the Middle East, and what was the Soviet Union. Rice, the staple grain of Asia, is not usually fed to animals.

Thus, reducing livestock herds to release feedgrains for human consumption affects few markets.

In those markets, however, the impact can be significant. In 1974, for example, there was a large shortfall in the maize crop in the US, but concurrent reductions in livestock and poultry freed up almost 30 million tons of grain. The US was, therefore, able to sustain its maize exports and food supplies for other countries. Without this released grain, prices on world markets would have been much higher.

As some point out, the land devoted to growing feed grain could be planted to alternative, higher value crops better suited to human tastes and nutrition.

is responsible for more than half of US water pollution, at a cost approaching US$41 billion a year; finally, the use of more than 80% of the country's water supplies for irrigation is depleting groundwater stocks.

"Green Revolution" agriculture, one of the most remarkable advances in food production, is practiced on uniform, resource-rich, often flat and irrigated areas in the agricultural heartlands of some developing countries. It is more widespread in Asia, but is also found in parts of Latin America and North Africa. As a result of the Green Revolution, many countries dramatically expanded their cereal production, particularly rice, wheat, and maize. India, for example, doubled its wheat production in 15 years; the Philippines increased its rice yields by 75%.

But success has its price. The "Green Revolution" varieties are not so much high yielding as highly responsive to fertilizers, pesticides, water and other inputs, all of which have become increasingly expensive as the cost of fuel has increased. Although cereal yields increased slightly more than 200% between 1960 and 1980, for instance, fertilizer use increased by 285%. In the island state of Singapore, fertilizer use per hectare in 1986 was almost four times higher than in 1976, a whopping 1,391 kg per hectare.

Resource-poor agriculture, by contrast, relies on little if any fertilizer or pesticides, and on uncertain rain rather than irrigation. It is

usually found in developing regions that are difficult to farm and have fragile soils. Much of Africa practices this type of agriculture, characterized by a large agricultural labour force and low yields.

Statistics for agricultural mechanization are also telling. Not surprisingly, Africa has the world's largest agricultural workforce. Along with Japan and Oceania, North America has the smallest agricultural workforce. Europe was by far the most heavily mechanized reflecting the continent's highly intensive agriculture and high rate of agricultural subsidies.

Increased mechanization and liberal applications of fertilizer translate into rapid increases in the use of energy, particularly fossil fuels. In "World Agricultural Changes, Implications for Canada," agricultural economist, J.C. Gilson, states that between 1950 and 1985, global tractor fuel consumption for agricultural production increased from 143 million to 739 million barrels of oil equivalent; that oil used to manufacture fertilizer increased from 70 million to 646 million barrels. For countries without domestic oil sources, the cost of importing oil to fuel mechanization is obviously enormous.

The area of cropland under irrigation follows similar patterns, but not everywhere equally; for example, between 1975 and 1985, yields of roots and tubers rose by only 2% in South America, but by 57% in Asia.

Future prospects

If the world's larder seems adequately stocked today, it may not be so in a few years. According to the Food and Agriculture Organization of the United Nations (FAO), food output needs to increase by 40% in the 1990s to keep up with world population growth and higher expectations born of higher incomes. In May 1989, the World Food Council reported that growth in food production was losing momentum and has been steadily declining in the Third World's poorest 69 countries.

The most important limiting factor is the lack of new land on which to grow food. Estimates say that arable land is unlikely to increase by more than 5% by the year 2000. Potential new land is unequally distributed — the most populous countries have the least land to spare— and much of it is marginal. What is more, large tracts of existing croplands are being rapidly degraded: by the late 1970s, soil erosion exceeded soil formation on about a third of US cropland, much of it in its wheat and corn belt. In 1984, a Standing Committee on Agriculture, Fisheries, and Forestry reported to the Senate that soil degradation has been costing Canadian farmers $1 billion a year. In India, soil erosion affects some 30% of the total land under cultivation.

The major nutrients that sustain plant growth are phosphorus, potassium, and nitrogen. There is no lack of potash and phosphate in the world, but they are unevenly distributed. North America is well

endowed with both, whereas South America must import large quantities of fertilizer. North and West Africa have large reserves of phosphate: the world market may depend on large exports from Morocco. As a whole, however, Africa is lacking in known reserves of potash. Asia has little of either fertilizer. This pattern of distribution emphasizes the interdependency among nations for vital resources and the importance of exchanging resources through an effective trade system.

Energy shortages also constrain production increases. US agriculture, for example, depends on huge expenditures of energy: as early as 1973, scientists reported that farming one hectare of corn in the US required the equivalent of 660 litres of fuel. Some 47 litres of fuel equivalents were needed just to offset the loss of fertility due to soil erosion.

Shortages of water, money, and land restrict the scope for new irrigation schemes in developing countries. What is more, some experts predict that many dams and irrigation schemes will become inoperable within 25 years because the technology used did not take into account factors such as the rapid erosion that can occur in tropical areas. In addition, inadequate drainage, seepage from unlined canals, and the overwatering of fields from as many as half the world's irrigation schemes have led to waterlogging and salinization of the soil. As a result, FAO and the United Nations Educational, Scientific and Cultural Organization (Unesco) estimate that as many as 10 million hectares of irrigated land are being abandoned each year.

The roots of dependence

From now until the end of this century, more than 86 million new food consumers will be added annually to the global community. These new consumers will demand an additional 28 million tonnes of grain, 1.6 million tonnes of red meat, and 5.6 million tonnes of oilseeds and oilseed products yearly. Most of these new consumers will be in the developing countries. Unless agricultural production booms in these countries, the world's poorest will depend increasingly on the North to improve the diets of their rapidly growing populations. A small number of industrial nations will grow in importance as the chief source of trade in primary food commodities.

This, of course, assumes both the continued productivity of northern countries' agriculture as well as the developing countries' continued purchasing ability. During the past few decades, the North's productivity has been phenomenal: not only have the member countries of the Organisation for Economic Co-operation and Development (OECD) achieved food self-sufficiency, but they are overproducing to the degree that accumulated food stocks are often a burden.

Canada is a case in point: between 1971 and 1981, its production of wheat exceeded consumption requirements by close to 400%. Except for significant imports of sugar, sheep meat, and vegetable and

tree-fruit crops, Canada is close to self-sufficient in most agricultural commodities. About half of Canada's cash farm receipts are derived from export sales, including 75–80% of wheat sales, 60–70% of canola, 40% of barley, and 25% of hog sales.

The South's increased reliance on the North to meet basic food needs is being encouraged by some on the grounds of efficiency. As US Secretary of Agriculture, John Block, said recently, developing countries should "adopt a more realistic food strategy based on the ready availability of cheap US cereals," rather than seek greater food self-reliance.

But the developing world's dependence on food imports has already reached unsustainable levels. The economies of these countries are still largely agricultural: close to a third of their exports come from their agricultural sector. Economic expansion must, therefore, rely on this sector. As studies have shown, there is a direct relationship between the rate of growth in the agricultural sector of developing countries and their expansion in import of agricultural and other commodities.

But worldwide average commodity prices dropped a third between 1980 and 1989 and are now at historically low levels. What is more, debt service payments reduce import capacity. Consumers in regions such as sub-Saharan Africa, where imported cereals account for as much as a quarter of cereal consumption, are already dangerously exposed to the vagaries of the world markets. World Bank figures indicate that the fall in prices left the purchasing power of sub-Saharan Africa's exports some 15% below the level reached in the 1970s. This points to the urgent need for global agricultural trade reform.

Escalating trade conflicts among the major trading countries, in fact, have created enormous instability in global trade and imposed a heavy cost on consumers and taxpayers. Worldwide spending on agricultural programs — estimated by the OECD to have surpassed US$200 billion in 1988 — has not resolved fundamental farm problems in industrial countries and has accentuated the difficulties of many of the developing countries.

Trading on hunger

The expansion of world trade in food in the past decades has been staggering: trade volume quadrupled between 1950 and 1980. Today, about one in every 10 grains crosses an international border between the time it is harvested and the time it is consumed, according to the World Resources Institute.

Agricultural trade issues are at the centre of the developing countries' relationship with the industrialized countries. Cereal imports by developing countries make up the largest growth area in world agricultural trade. This is despite most developing countries' efforts to increase

agricultural productivity and considerable foreign aid being extended to help them do so.

Food imports may be providing the marginal increase in calories that millions of people need, but relying on other nations for as basic a need as food is politically and economically risky. Over the past 15 years, for example, almost every African country has increased its volume of cereal imports and of food aid in cereals. This growing reliance on food from exporting countries increases the vulnerability of these countries to outside sanctions. As the UNDP notes in the 1991 Human Development Report, an increasing proportion of aid in recent years has been conditional on the recipients changing domestic policy in line with the donors' views.

As early as 1966, for instance, the US government made its food aid to developing countries conditional on their adoption of Green Revolution techniques. The aim was to boost agricultural production. But it also served to expand American tractor and chemical sales and fostered production increases over land redistribution as a means of promoting social stability in the recipient countries.

Furthermore, in 1985 the US implemented two new assistance programs aimed at strengthening agricultural production: essentially, the US offered aid to those countries that agreed to reform their agriculture, stressing market approaches. Canada and other industrialized countries followed suit. African countries committed themselves to investing 20–25% of their public investments in agriculture and to measures to combat drought and desertification.

But as Douglas Roche, Canadian Ambassador for Disarmament from 1984 to 1989 points out, Africa is now worse off than 5 years go when famines took 2–3 million lives. A recent U.N. report says that up to 30 million Africans face starvation and malnutrition.

Although war, civil strife, and climatic calamities can be blamed for this situation, so can trade. Prices for key African commodities such as cocoa and coffee plunged, reducing African export earnings by $50 million. At the same time, costs of key commodities such as oil skyrocketed and the North reduced resource flows to Africa from $25.9 billion in 1986 to $22.6 billion in 1989. In fact, most of the world's poorest countries depend for increasing export earnings on tropical agricultural products that are vulnerable to fluctuating or declining terms of trade. Expansion can often only be achieved at the price of ecological stress.

The extent to which trade in agricultural commodities increases will depend largely on the progress made in reforming domestic agricultural and trade policies in the Uruguay Round of the General Agreement on Tariffs and Trade (GATT). Trade between North and South should certainly increase if developing countries are to become more completely integrated into a liberal trading agreement than they have been.

Subsidizing excess

Agricultural policy in OECD countries has been accused of transforming agriculture into a machine to produce costly surpluses. In 1985, for instance, the US' unsold agricultural products amounted to 13% of its total production. The E.C.'s surplus of cereals were valued at some US$3.7 billion in mid-1986 and cost the community US$634 million in storage and interest costs; its stocks of animal products — butter, beef, and skim milk powder — were costing US$955 million a year. The problems associated with these surpluses spread to other countries as the E.C. began to dump them in foreign markets.

Food surpluses in North America and Europe result mainly from subsidies and other incentives to producers that stimulate production whether or not there is a demand. Direct or indirect subsidies are very expensive; in the US, the cost of farm support was $25.8 billion in 1986, and in the E.C., it was $21.5 billion. Over a third of farmers' incomes in both was provided by government payments. Canadian government transfers to agricultural producers that same year totalled $7.85 billion, equivalent to 43% of total agricultural income.

Dr Alberto Valdes, economist with the Washington-based International Food Policy Research Institute (IFPRI), points to the consequence: agriculture is the sole major sector in which a high proportion of production is sold on world markets at less than domestic prices. This depresses the international market prices of commodities and creates severe problems for developing countries whose economies are based on agriculture. The UNDP estimates that protectionism costs developing countries US$100 billion a year in lost revenues from agricultural products alone. Thailand, for instance, saw export prices for rice fall from $230 to $170 a ton in 1986 as the US attempted to gain market share by dumping excess production. For the first time in 20 years, rural poverty increased as the price slump hit the country's 2 million smallholder rice producers.

Industrialized countries are not immune. This past year, Canadian wheat farmers bore the full brunt of the E.C. and US subsidies as the price for their crop plummeted. Widespread bankruptcies were prevented only at the cost of $800 million in emergency government aid.

Attempts to encourage greater food self-reliance also suffer when cheap cereals flood local markets. Keven Watkins, member of British aid agencies' U.K. Food Group, says that at the height of the 1980s trade hostilities, the US and the E.C. were dumping wheat produced at a cost of $180 a ton at prices as low as $60 a ton in West Africa, a third lower than equivalent production and marketing costs for peasant-produced staples such as sorghum and millet. Peasant producers were thus forced out of the local market, and, sometimes, off their land.

At the same time as they implement export-enhancement policies, the industrial countries implement import protection measures.

Not-so-sweet deals

Sugarcane is big business in the Third World. It supports 30 million people and generates $16 billion in exports, nearly 20% of their earnings from all agricultural exports, according to FAO. Some small states, including Fiji, Mauritius, and several Caribbean islands, depend for their economic survival on cane sugar exports.

Many developing countries have a genuine comparative advantage in cane production; cane, cultivated mostly by hand in plantations, costs about $0.10–$0.12 a pound to produce. The alternatives, corn syrup in the US and beet sugar in the E.C., cost $0.13 and $0.19 a pound, respectively. Even Canada has a sugarbeet industry. Yet, Europe has closed its border to cane sugar imports, and the US props up its cane and beet growers with guaranteed prices and strict import quotas.

Sugar protectionism is on the rise. From a net importer of sugar 20 years ago, the E.C. is now the second largest exporter. The reason is guaranteed high prices for domestic sugar, averaging $0.30 a pound, and lavish subsidies for export. These exports then suppress the world market price. In 1986, the World Bank estimated that industrial countries' sugar policies cost developing countries about $7.4 billion in lost revenues — more than twice as much money as they receive in food aid from those same nations. As the European Consumers' Organization pointed out in June 1991, European consumers are paying high prices for sugar to finance the dumping of overpriced, overproduction on the world market.

The few imports allowed in both the US and the E.C. are from preferred allies. Trinidad and Jamaica, for example, can sell more sugar to the E.C. than they produce; they, therefore, buy cheap sugar on the world market for their domestic needs and sell their raw cane at a premium. Some of that sugar in turn, ends up dumped back on the world market by the E.C., further depressing prices.

But, reported World Watch in its June 1991 issue, there is a sour note to some of these sweet deals. Between 1982 and 1987, the US cut its imports by 70%. The Dominican Republic, consequently, saw its quota shrink to a third of its original amount. Faced with selling its excess production at low world market prices, it slashed production and exports. From a profit of $102 million in 1984, the Dominican Republic's sugar industry was losing $17 million a year by 1988. By 1990, four sugar mills had closed and thousands had lost their jobs.

When it tried to sell its sugar on the world market, it found that US protectionism had depressed prices for sugar by 21–50% during the 1980s, whereas the E.C. sugar policies had dragged it down another 5–12%.

What is more, the production of beet sugar in industrialized countries has had adverse ecological effects. Beet growing is capital intensive and depends heavily on chemical herbicides. The same product can be grown in developing countries as cane, more cheaply, using more labour and fewer chemical additives.

The effect is significant. Thailand, for instance, is a large exporter of rice and cassava and is, therefore, vulnerable to US domestic rice-pricing policies and to E.C. policies that discourage the import of feed substitutes such as cassava. Countries that export vegetable oils, such as palm oil and peanut oil, are in increasing conflict with the E.C.'s highly subsidized oilseeds sector. Cane sugar producers are hindered by US and E.C. import restrictions designed to protect domestic beet sugar and corn syrup (see page 16, "Not-so-sweet deals").

In its 1985 report, the World Bank pointed out that nearly 30% of the developing countries' agricultural exports to the industrial countries were restricted by quota restraints or nontariff barriers. It calculated that the liberalization of North and South agricultural policies would increase food prices and encourage agricultural output in the developing countries, which could result in a US$18.3 billion income gain.

Buyers and sellers both suffer from export subsidies and supports. Countries that can not sell food as cheaply as the subsidized exports are deprived of the opportunity to supply the world market. As consumer groups in exporting countries point out, domestic consumers also suffer. In 1989, Europe's Common Agricultural Policy (CAP) cost European consumers an extra US$24 a week for a family of four.

When northern marketing practices reduce commodity prices, farmers in the South switch their crops to products for which there is a lucrative market: coca leaf in South America, and opium poppies in the Golden Crescent, Mexico, Thailand, Myanmar, Laos, and Guatemala where they are displacing fruits and vegetables over thousands of hectares.

Stalemate at the GATT

The two exporting giants are now at loggerheads as both the US and the E.C. struggle to set world agriculture on a different footing. Their negotiations are being carried out under the auspices of the GATT.

The dispute concerns the amount by which farm production is subsidized. According to the OECD, agricultural support costs its member countries about $72 billion (at 1988 prices) and may cost consumers three times as much in taxes and higher prices. Worldwide spending on agricultural programs topped US$200 billion in 1988.

The US wants free trade in agriculture and is pressing for reductions of 75% in most supports and 90% in export subsidies. The US position is supported by a number of food-exporting countries, both rich and poor. Canada supports greater trade liberalization, although it too has a variety of price- and income-support measures and a range of import restrictions to protect its agricultural producers. The E.C. has offered 30% cuts in overall support by 1996 and no commitments on export subsidies.

The bitter taste of coffee and chocolate

In 1980, coffee generated some $12 billion in export earnings, second only to petroleum. Impressive revenues, no doubt, but it represents only a fraction of the price of a jar of instant coffee in the supermarket. Of the price you pay, only 4–8% goes to the producer, whereas 19% goes to the producing country. An equal amount is paid to the traders, brokers, and shippers of the coffee beans, most of them in industrialized countries. Most of the coffee drunk is soluble, i.e., instant, and turning beans into powder is a profitable business; 25% of the cost of the jar you buy goes to processors and wholesalers, the retailer then earns another 20%.

Only about 4% of coffee exported from developing countries is processed there. This is because a few giant corporations, backed by protectionist governments, can dictate terms of trade to producer nations. When Brazil started to market its coffee powder in the US some years ago, for instance, it was threatened with an end to all coffee-trade agreements, even a cut-back on US aid.

Coffee producers are now in disarray; when their system of export quotas broke down in 1989, stocks flooded the market and prices dropped by almost half. The abolition of quotas is estimated to have cost Brazil — the world's top producer — $1 billion in lost revenues. Brazilian production has also fallen because of poor weather, deteriorating soil conditions, and cutbacks in marginal areas. No new agreement is in sight.

Brazil is also the world's second largest producer of cocoa. Prices of cocoa, one of the world's top three agricultural export products, have also been falling sharply because of overproduction. Although cocoa was introduced into Africa only at the beginning of the 19th century, three African countries now figure in the world's top five producers and exporters: Ivory Coast, Brazil, Malaysia, Ghana, and Nigeria.

The first international cocoa agreement aimed at stabilizing the market was signed in 1972, but failed, largely because producers did not to limit their production, which increased faster than demand. A large part of the overproduction is caused by Malaysia's 10-fold expansion in output in as many years. Demand, meanwhile, has stagnated. Prices in 1989/90 were at a 14-year low.

The situation is similar for other export crops. In 1982, authors Susan George and Nigel Paige estimated that of some $200 billion a year spent on agricultural products originating in the Third World, the producing countries received about $35 billion, or 15%. The rest went to intermediaries, mainly multinational companies. The producer's share of the purchase price was even smaller: 4% for coffee, 5% for tea, 6% for bananas, and 13% for cocoa.

Critics point out that subsidy and price cuts for European and American farmers will not necessarily reduce the kind of overproduction that led to dumping in the 1980s. In fact, if small family farmers in both regions are bankrupted as they lose their subsidies, farming will become increasingly concentrated on more capital-intensive, highly productive farms. Intensification on this acreage could actually increase surpluses.

Massive subsidies have not benefited all farmers equally. British Member of Parliament George Stevenson reported in 1991 that three-quarters of Common Agricultural Policy payments go to the largest 20% of farmers, exporters, and agribusiness interests. Smaller farms, he says, have not been able to protect themselves from soaring costs.

Speaking in Ottawa this past May, Uruguayan President Luis Alberto Lacalle Herera described economic protectionism as "the biggest danger facing his country." In particular, he stressed that the E.C.'s subsidies to farmers make it all but impossible for Uruguay to compete.

Developing countries could be threatened by the US' drive to open their food economies to world market forces, however. As the quarterly publication of the London Food Commission, *The Food Magazine*, reported in early 1991, the US proposals would allow developing countries to support their farmers only if it had "no or a minimal effect on trade"; and if it did not act to maintain domestic prices at higher than world market levels. That means that border restrictions on cheap food imports would be outlawed, exposing millions of rural producers to world prices dictated by E.C. and US surpluses. The results? "Efforts to raise food production, maintain rural employment and encourage ecologically sensitive agriculture would suffer," says *The Food Magazine*.

If trade liberalization is to promote growth, development, and trade in developing countries, they will need to be accorded special treatment. The statement of principles of the Uruguay Round recognizes this, but agricultural economists consider that global trade liberalization will also require substantial changes in national agricultural policies and that trade policies will need to be closely integrated with the development policies of the World Bank and International Monetary Fund.

Some critics argue, however, that "free trade" and "world market prices" essentially mean unhindered competition between farmers, regardless of size and location, with no consideration for environmental and social costs. For smallholders, they say, it makes no difference whether the GATT talks succeed or fail; big farms and corporate agribusiness will profit regardless.

No free lunch

Food aid links the North's surplus-producing agricultural areas with countries in need. When recurring drought, massive floods, insect

plagues, and civil war caused major food calamities in China, Nigeria, Bangladesh, India, and in several countries in Central and South America and sub-Saharan Africa during the past 25 years, for instance, international food aid prevented mass starvation.

Cereals make up the largest part of official development assistance food aid programs, with vegetable oils and milk coming distant seconds. According to the 1991 Human Development Report, in 1987–88, food aid in cereals accounted for 18% of the developing countries' cereal imports of more than 105 million tonnes. In sub-Saharan Africa, food aid in cereals accounted for 42% of cereal imports.

The major donors of cereal food aid are the US, the E.C., Canada, Japan, and Australia. In the Global Food Assessment report, published in late 1990, the US Department of Agriculture reported that the value of all food aid donated by the OECD countries was a record US$3.6 billion in 1988, the last year for which data were available. The portion of food aid provided as grants rose to more than 80% (all of Canada's food aid is provided as grants). Food aid's share of total official development assistance was about 8%.

Although emergency food aid has long been an important way of helping low-income countries sustain domestic food supplies, food aid is also given in nonemergency situations on a bilateral (country-to-country) or a multilateral basis, mostly through the World Food Programme, as well as through nongovernmental organizations. It is given to governments for domestic sale, enabling them to earn revenue for balance-of-payments and budgetary support. Because the food provided is generally free, cash is liberated for social and other programs. A smaller part is given as a component of agricultural, rural development, and nutrition projects and to establish food security reserves.

A more recent food aid mechanism is the provision of funds by donors for food purchases from neighbouring countries. Although these triangular transactions offer great potential, in practice they account for a small percentage of total food aid because of a lack of funds and uncertainty of suppliers.

Although essential, food aid can have some less-desirable effects. The sale of grain donations to local citizens through national marketing channels augments general revenues and reduces the need to tax more heavily, but it can also hold domestic farm prices below levels that would prevail if the imports were not available, thus destroying incentives to increase local food production. As W. David Hopper, a former president of IDRC, put it: "developing nations, in effect, farm the fields of Kansas and Saskatchewan and are paid for doing so."

According to the World Bank, food aid does little to help countries cope with food insecurity resulting from higher food prices on the international market. Fixed budgets for food aid provide less food when prices are higher. Even worse, these budgets are often reduced when prospects for commercial exports improve.

As the Brandt Commission noted, continuing dependence on food aid also encourages consumption habits and tastes that cannot be met from domestic production.

The USDA estimates that in 1990/91, 16 million tons of food aid were required to maintain cereal consumption levels of previous years in 55 recipient countries. But to meet each country's minimum caloric standard determined by the U.N. (roughly 2,000 calories a day per person), 26 million tons would be needed. That year, only about 12 million tons of food aid were available.

According to Richard H. Young in "Addressing the Human Dimension: In Nutrition Sciences, Agroindustries, and International Agricultural Research" (IDRC-285e), although food sharing may have been a major determinant in the development of humans at Olduvai Gorge, in Tanzania, some 2 million years ago, it clearly is not so today. Food — and the capacity to grow food — is inadequately distributed among the world's population. Indeed, the numbers of hungry people are growing. Largely as a result of economic and political factors, stockpiles of "excess" food coexist with hunger and malnutrition.

The World's Supermarket

A mere total of 20 plants provides 90% of our food — yet walk into any North American supermarket and you will see products from as many as 100 different plants, some of which were unknown to us even a few years ago. This abundance of fresh fruit and vegetables from every comer of the globe has eliminated distance and seasons from our tables; we can feast on the tropics in January, without ever leaving home. Meanwhile, millions of Third World citizens are supping on grain and milk from North America and Europe. Through global trade and the integration of the world economy, we get much of our food from a global farm, through a global supermarket — a result of advances in food technology over the past 40 years.

Most nations' diets are essentially similar: four crops — wheat, rice, maize, and potato — contribute more food to the world's total food production than all other crops combined. The world's population depends on 30 crops for 95% of its nutrition and a mere eight crops provide three-quarters of its diets. This is a relatively recent phenomenon; ancient hunter–gatherers exploited hundreds of plants and dozens of animals for food. As domestication followed domestication, early agriculturalists assembled a small group of plants and animals that served their basic needs. These same food sources still meet our needs today.

This globalization of basic food sources means that a growing proportion of us are feeding from a common bowl. As the trend intensifies, we become increasingly vulnerable because our food supply depends on an ever-smaller number of species, many of which grow in narrow latitudes; failure of one of them may mean hunger for millions of people.

In the pages that follow, we explore how agriculture in the North and South meets its citizens' food needs.

More than bread alone

The average adult needs about 2,500 calories of food energy a day. But not everyone gets that — people in industrially developed countries enjoy 800 or so extra calories a day, whereas their counterparts in the developing countries make do with two-thirds as many.

As important as total calories consumed is the amount of protein that is essential for body growth and development. The World Health Organization's (WHO) recommendation for full protein consumption is 65 grams per person per day. Citizens of poorer countries consume

less than 60 grams of protein daily, whereas North Americans consume at least 100 grams.

Calories and protein come from five categories of food: cereals, legumes, meat and fish, fruit and vegetables, and roots and tubers, although the latter two groups provide little protein. Cereals provide about 90% of calories consumed and 65–75% of world protein. They also make up the bulk of world food trade. Half of the world's total cereal production is made up of three cereals: wheat, rice, and maize. That cereal production has kept pace with demand is largely the result of international efforts, channelled through a network of specialized international agricultural research centres (IARCs) located throughout the developing world (see page 25, "Supporting international agricultural research").

Wheat is the most important agricultural commodity in international agricultural trade. In the 60s and 70s, the introduction of high-yielding varieties of wheat developed at the International Centre for the Improvement of Wheat and Maize (CIMMYT), located in Mexico, spurred a phenomenal increase in the Third World's production. The area planted to high-yielding wheat varieties in South Asia went from nil in 1965 to more than 25 million hectares by 1982. But, although wheat is now grown in many countries and regions, from Australia to Canada, Turkey to China, it does not do well at low latitudes in warm climates. The bulk of production and of trade is, therefore, quite highly concentrated.

As a result of large-scale grain trade, wheat products, particularly bread, have become basic staple foods in developing countries, and consumption is rising at a rate of about 4.5% a year. Much of this increase is because of the high rate of urbanization and increased incomes, but wheat products are also becoming popular with poorer groups and in rural areas where they are displacing traditional, local coarse grains, roots, and tubers in people's diets. Price is also an attraction; through favourable import rates for wheat and consumer subsidies for bread, prices have been kept low relative to local staples. Wheat provided as food aid has also fostered a taste for bread in both groups; as a result, local flour mills, bakeries, and pasta factories have been established, providing employment and income as well as food.

To reduce dependence on imports, many countries of the South are looking at the possibilities of producing their own wheat. Studies have shown that reasonable yields are possible in many areas. The best prospects are in areas where the land is left fallow during the dry cool season but where sufficient stored moisture is available to support a low-yielding crop of wheat with low levels of inputs. But, unless advances are made to breed wheat varieties able to withstand heat and disease, it is not likely to become a significant tropical crop.

More promising are efforts under way to substitute flours from local cereals and tubers for part of the wheat flour in convenience products such as bread and pasta. Projects carried out in Africa and India with support from IDRC, for instance, have succeeded in adapting

Supporting international agricultural research

The Consultative Group on International Agricultural Research (CGIAR) is an international group of donor agencies, agricultural scientists, and institutional administrators from developed and developing countries who guide and support the 16 international agricultural research centres (IARCs) of the CGIAR network. Each centre specializes in its own field of research: crop-specific research, research on agriculture in the dry areas, livestock rearing, agricultural economics, etc. IDRC has provided substantial support for CGIAR since its creation in 1971.

Current CGIAR centres are:

Centro Internacional de Agricultural Tropical (CIAT), Cali, Colombia: focuses on crop improvement and on improving agriculture in the lowland tropics of Latin America.

Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT), Mexico: focus on improving maize, wheat, barley, and triticale.

Centro Internacional de la Papa (CIP), Lima Peru: focuses on potato and sweet potato improvement.

International Board for Plant Genetic Resources (IBPGR), Rome, Italy: focuses on conserving gene pools of current and potential crops and forages.

International Centre for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria: focuses on improving farming systems for North Africa and West Asia.

International Council for Research in Agroforestry (ICRAF), Nairobi, Kenya: focuses on the development of appropriate agroforestry systems and technologies.

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Andhra Pradesh, India: crop improvement and cropping systems.

International Food Policy Research Institute (IFPRI), Washington, D.C., USA: focuses on strategies and policies to meet world food needs.

International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria: focuses on improving crops for the humid and sub-humid tropics, land management, and farming systems.

International Irrigation Management Institute (IIMI), Kandy, Sri Lanka: focuses on improving irrigation systems through management innovations.

International Livestock Centre for Africa (ILCA), Addis-Ababa, Ethiopia: focuses on farming systems (livestock and forages) incorporating ruminant livestock

International Laboratory for Research on Animal Diseases (ILRAD), Nairobi, Kenya: focuses on the control of major livestock disease in sub-Saharan Africa.

International Network for the Improvement of Banana and Plantain (INIBAP), Montpellier, France: focuses on improving the production of banana and plantain.

International Rice Research Institute, (IRRI), Manila, Philippines: focuses on global rice improvement.

International Service for National Agricultural Research (ISNAR), The Hague, Netherlands: focuses on strengthening developing-country agricultural research systems.

West Africa Rice Development Association (WARDA), Bouake, Côte d'Ivoire: focuses on rice improvement for West Africa.

processing techniques and machinery, as well as recipes and markets, for traditional crops such as sorghum, millet, cowpeas, and cassava.

In much of the world, rice is more important than wheat; it is central to the diet of about half the world's population, mainly in the developing countries where it is grown. Little of the world's estimated production of 345 million tonnes enters international trade. China and India are the world's largest producers, for example, and they consume virtually all their domestic production. Thailand and the US are the main rice exporters.

Rice's recent past is a story of success. During the last 30 years, the introduction of high-yielding varieties through the International Rice Research Institute (IRRI), based at Los Baños in the Philippines, has succeeded in boosting production by 66%. As a result, many Asian countries achieved food self-sufficiency, the real price of rice was halved, and predicted famines have been averted. Today, farmers can grow up to three crops a year on land that previously grew only one.

But the future may not continue to be as bright. To feed a growing world population, rice production will need to grow by at least 10 million tonnes a year. Although that is not a huge amount, these gains may not come easy; Asia's irrigated lands are becoming increasingly saline, soils producing three crops a year are being depleted of nutrients, and insect infestations are increasing. "The Economist" reported in March 1991 that yields were showing a long-term decline even on IRRI's model farm. Outside that farm, the problem of declining yields is compounded by a loss of prime cropland.

IRRI researchers are now attempting to breed a new super-rice that combines high yields with vigorous growth and resistance to diseases and insects, that can withstand both drought and floods, salty water, and other hostile environments.

Maize — corn — is the world's third largest cereal crop and the only one indigenous to the Western hemisphere. The staple food of ancient civilizations, it is now also the staple food of at least 500 million people in Africa, Asia, and Latin America. Maize's protein content is a respectable 9.5% compared to 8–15% for wheat and 8–9% for rice. In 1985, it provided 19% of the world's food calories and 15% of the protein derived from food crops. Some believe that maize is a major potential contributor to additional future food supplies in many developing countries.

Maize's story is also one of success. In the mid-1960s, dwarf, high-yielding varieties were developed at CIMMYT in Mexico and introduced in India and Pakistan. CIMMYT is cooperating with another centre, the International Institute of Tropical Agriculture (IITA) in Nigeria, and scientists in about 100 countries are participating in the maize improvement efforts. Progress is being made. A notable example is the release in 1989 of high-yielding maize that can be grown in the toxic, high-aluminum soils of Brazil's vast Cerrado plateau. Large areas

of Africa with similar aluminum toxicity might be candidates for related cultivars.

In the industrialized countries, efforts of government-sponsored research are supplemented by seed companies. Pioneer Hi-Bred International Inc., headquartered in Des Moines, Iowa, for example, has 25 maize-breeding stations in the United States and Canada. The experimenters are seeking maize hybrids that have stable performance across a number of environments.

According to researchers, maize will become increasingly important in the future because both wheat and rice have reached their maximum area for adaptation. Maize, however, thrives in more diverse environments than any other major crop, from sea level to high altitudes in both temperate and tropical climes.

Tropical roots

After cereals, roots and tubers are the most important staple foods. Some 550 million tonnes of roots and tubers are harvested annually. Yet, until recently, roots and tubers received low priority in developing countries' agricultural plans, and populations quickly set them aside when cheap cereals became available.

One exception is the potato, a staple of northern diets that is now strongly taking root in the South. It has found a home in countries such as China and India. Developing countries, in fact, now produce a third of the world's potato crop.

Rich in potassium, iron, magnesium, vitamins B and C, and complex carbohydrates, potatoes have better-quality protein than soybeans and are essentially fat-free. The potato, in fact, can supply more nutritious food faster, and with less land, than any other widely grown food. A hectare of potatoes yields twice as much protein as a hectare of wheat. Scientists at the International Potato Centre (CIP) in Lima, Peru — the ancient home of the potato — describe it as "the true treasure of the Andes." It is estimated that the annual world potato crop is worth more in dollar terms than all the gold that was carried out to Europe from the Americas in almost 400 years of colonial history.

At a symposium held in October 1990, CIP scientists described the revolution in potato research as they work on breeding varieties that better resist pests and diseases and can adapt to an even wider range of environments. Although there is no such thing as a "magic bullet" capable of eradicating world hunger, CIP scientists optimistically believe that the potato could do for the tropics what it did in Europe in the 18th century when the secure food supply it provided paved the way for the Industrial Revolution.

Adaptable and hardy, potatoes will grow almost anywhere, even in deserts, provided the temperature drops at night. Because they are a root crop, they can withstand conditions that grains cannot. In

temperate climates, potatoes can take up to 150 days to mature, but in tropical climes, they can be harvested in as few as 40–90 days; that enables farmers to sandwich a crop of potatoes between crops of slower growing cereals, making land much more productive.

More than 5,000 varieties of potatoes are being maintained at CIP in an effort to sustain the genetic diversity of the crop and to serve as a source of germplasm for breeding new varieties. Work is focused on incorporating genes for disease resistance because the high temperatures and humidity of the tropics make potatoes more vulnerable to pathogens.

Both North and South have a stake in the success of this and other work aimed at making potatoes pest- and disease-resistant. The Irish famine of the mid-1800s has not been repeated, but it could be; with only six varieties accounting for 80% of American and Canadian potato production, the appearance of a chemically uncontrollable disease or pest could spell disaster.

The researchers are also concentrating on changing the way in which potatoes are planted. Potatoes are traditionally planted using the tubers themselves, which is cumbersome, costly, and potentially risky because the tubers can spread disease that are not found in seeds. Prince Edward Island's seed potatoes — a $40 million crop — are proof of the hazards. In 1990 and 1991, the tubers were banned from the US and the rest of Canada because they harboured the PVYN virus, hitherto found only in Europe. To control the disease, farmers were told in August 1991 to plow the crop under and seek government compensation.

CIP has revived the ancient Peruvian practice of growing potatoes from seed, abandoned because potato seed does not breed true. But CIP researchers found that many growers in developing countries were less concerned about producing uniform plants than about producing plentiful food at low cost. To plant a hectare using varied seed would cost only about US$50, compared to US$1,250 when using tubers. To date, more than 40 developing countries have adopted seed planting.

But because tuber planting remains the dominant planting technique, CIP developed a rapid-multiplication technique that involves growing seedlings first in virus-free conditions in test tubes before transferring them to screen houses where they produce tubers for planting. Close to 30 developing countries now have their own tissue-culture programs, reducing the need to import expensive tubers. In Vietnam, it has been so successful that potatoes have become the second biggest crop, by weight, after rice.

Another tropical root is becoming more visible in the North's produce markets, both in fresh form and as snacking chips — cassava. But it is not a recent arrival; we have been eating cassava for years in a processed form known as tapioca. Cassava is the staple diet of poor people in many parts of the world. Usually grown by small farmers, in marginal soil, the starchy staple feeds 700 million people and provides

more than half the calorie needs of 200 million Africans. The hardy, drought-resistant plant can withstand high temperatures and dehydration. Because the starchy tuber can remain in the ground for months after maturity, it is often used as an emergency food reserve. Once harvested, however, the root spoils quickly. Many growers counter this problem by sun-drying the roots.

Close to 85% of the solid part of the cassava root is starch, which gives the plant considerable commercial potential, particularly as an inexpensive substitute for grains in animal feeds. Thailand, in particular, grows and processes cassava for the European feed market. In 1989, it exported some 7 million tonnes of sun-dried cassava pellets. During the 1980s, the chipping and drying techniques were introduced to cassava growers on Colombia's north coast. More than 50 farmers' associations have since been formed to dry and process cassava for the feed market. The idea has also spread to Ecuador where cassava flour and starch are used as feed for the country's valuable shrimp farming industry.

Cassava flour also helps wheat-importing countries; it can replace up to 15% of wheat flour used in bread and even more in other products. A pasta factory in Cali, Colombia, for example, replaces half the wheat flour with cassava. IDRC has supported research into the establishment of a cassava flour agroindustry in regions of the country where the tuber is grown. Cassava starch is also increasingly valued in modified forms for a variety of food uses.

To meet demand for the fresh cassava market, the International Centre for Tropical Agriculture (CIAT) in Cali, Colombia, in collaboration with the U.K.'s Natural Resources Institute (NRI), has developed an inexpensive treatment to prevent spoilage. Not only are farmers now using the method to package roots for urban markets but also for shipping to the US.

Much attention is also being focused on cassava's toxicity. Studies carried out in Zaire in the late 1970s, with support from IDRC, pointed to a link between a high cassava intake and endemic goitre and related neurological syndromes in areas where dietary iodine was in short supply. Cassava's cyanide content is to blame for the problem. Researchers have since discovered that the amount of cyanide left in cassava varies with the method of preparation; grating the raw roots and roasting the final product appears to eliminate most of the cyanide.

Pass the beans and peas

Once called "poor man's meat," legumes are an important source of protein. Soybeans, for instance, are the mainstay of vegetarian diets in North America where the bean is more commonly grown for oil and animal feed. The world's main oilseed crop, soybeans accounted for 30% of world edible oil consumption in 1988.

The United States is the world's largest soybean producer and

exporter, followed by Brazil and China. Canadian soybean production has increased sharply; a decade ago, we imported 60% of our requirement. Today, Canada is self-sufficient in soyoil production and exports beans to Asia where they are a popular food.

Soybean production has actually declined in Asia over the past 20 years. In Thailand, for example, production has dropped from 1,185 kg/ha to 562 kg/ha despite a seven-fold increase in the acreage under cultivation. The decline is blamed on planting techniques: because soybean planting is tedious, time-consuming, backbreaking work, farmers are resorting to broadcast seeding, which produces low germination rates, less uniform seeding, and lower yields. With assistance from IDRC, the Asian Institute of Technology (AIT) in Bangkok has now developed a mechanical seeder that could halve planting time while producing more uniform seeding.

Soybeans are also gaining ground in Africa, largely because of efforts of IITA in collaboration with the Institute of Agricultural Research and Training, also based in Ibadan, Nigeria. Research on soybeans has been one of IITA's priorities, and it has developed varieties that yield well under local conditions. With financial support from IDRC, both institutions also developed ways of easily processing and using soybeans so that they could be incorporated into local dishes, thereby improving their nutritive value, but without affecting the taste or the price. Surveys show that, in the past 5 years, the proportion of people eating soybeans has risen from near-zero to 54%. In Ibadan today, 15 food manufacturers produce everything from soy milk to nursing foods. Ghana is now studying the possibility of undertaking a similar program.

Cowpeas remain the most important legume in large parts of Africa, however. A traditional crop, they contain 23% protein. IITA has devoted much research to increasing the legumes' production by developing pest- and disease-resistant varieties adapted to the poor soils and uncertain rainfall of Africa's "hunger belt" south of the Sahel.

Striking oil

Fats and oils are crucial for good health. The most concentrated form of energy available to the body, oil also carries fat-soluble vitamins and is a source of essential fatty acids. These fatty acids are needed for normal growth and for the maintenance and proper functioning of many physiological processes. Vegetable oils are also a major source of vitamin E.

According to WHO, each of us requires 11 kilograms of oil a year for a balanced diet. Although a major nutritional problem in North America is reducing fats in the diet, the poorer developing countries face the opposite problem.

In India, for example, people consume on average only 5 kg of oil a year, and that despite the country's huge imports. In fact, the importa-

tion of edible oil is now the second largest drain on India's hard currency resources after petroleum imports.

Oils are not all created equal. On the one hand, in some studies, saturated fats like palm oil and animal fats have been shown to increase levels of blood cholesterol and thus increase the risk of heart disease. Evidence also suggests that polyunsaturated and monounsaturated fats, on the other hand, can lower levels of blood cholesterol.

A Canadian crop that produces one of the most nutritious edible oils, canola, may contribute to solving one aspect of those problems in a number of developing countries. Canola is the name given to varieties of rapeseed that are both low in erucic acid, which can be harmful to humans if consumed in large quantities, and in glucosinolates, which make rapeseed meal unpalatable and toxic to livestock, thus limiting its use as animal feed. It was developed in 1974 by Dr Baldur Stefansson, a plant breeder at the University of Manitoba.

Canada is the world's third largest producer of rapeseed, trailing China and India. Almost all the Canadian crop is canola, and Canadians are the world's largest consumers of canola oil; more than half our fat intake is in the form of canola oil. Canada exports canola oil the world over. In 1989, those exports were worth $111 million. Exports of canola seed, mainly to Asia, brought an additional $623 million.

Canola's nutritional credentials are impressive. At 4%, canola oil has the lowest saturated fat content of any edible oil and is second highest in monounsaturated fats (58%). It also contains acceptable levels of polyunsaturated fats as well as the essential fatty acids; linoleic acid, required for the development of cell membranes; and linolenic acid, a constituent of tissues in the brain and retina.

In India, officials believe that rapeseed and mustard, another oilseed of the brassica family, have the best potential for meeting the country's edible oil shortfall. To do so will require increasing production by developing high-yielding, disease-resistant varieties and by adapting the more nutritious canola to India's conditions. That is the thrust of a project, supported by IDRC, which is linking research institutes in India with their counterparts in Canada.

Canola is also making inroads in China where two varieties have been introduced in areas where the climate is similar to Canada's. Officials report that they are quickly overtaking older rapeseed varieties. In return, Canada is benefiting from China's disease-resistant rapeseed varieties. Chinese plants, especially those grown at high altitudes, are more resistant than Canadian plants to the fungi that cause root rot, a disease that plagues canola crops in Western Canada. Using genes from the Chinese plants, researchers at the University of Manitoba developed a new, rot-resistant strain of canola. If the plants live up to their promise through two more years of testing, they will be registered as new Canadian varieties and will be made available to farmers.

This exchange is the essence of the collaboration between

Canadian and Chinese researchers who, with support from IDRC, have been cooperating on canola research for many years. It is a two-way street as both countries benefit from the exchange of ideas, techniques, and germplasm (breeding material). In addition to Canada, China, and India, a number of other countries, such as Ethiopia and Pakistan, are also involved in canola development through their participation in an IDRC-supported research network on oil crops.

Canola is even spreading to the United States where the oil was approved for human consumption only in 1985. By 1989, fewer than 200,000 acres had been planted to the crop, but researchers consider it has a promising future.

Going bananas

Horticultural products may be the largest area for export growth for developing countries. From 1983 to 1985, the developing countries' share of world horticultural exports was 37% and rising. The Washington-based International Food Policy Research Institute (IFPRI) estimates that these exports could increase 1.6–3.4% a year by the year 2000, amounting to US$12–15 billion in 1985 prices, more if trade is liberalized.

One of the first tropical fruits to be imported by the North was undoubtedly the banana; the first shipload from Jamaica, for example, landed in Boston in 1872. Bananas are now such a common part of Canadians' diet that we have come to take them for granted.

Apparently a native of India, the banana was "discovered" by Alexander the Great in the Indus valley. Migrating populations carried the fruit to the Near East and Egypt, then to Africa and Spain, from there to the Canary Islands and into Central America in the 1500s. Spanish and Portuguese explorations and settlements spread the banana throughout the islands and along the shores of the Caribbean, a region that now supplies North America and part of Europe.

There is a widespread misconception in the North that bananas are grown by multinational agribusiness on vast plantations. This is perhaps true for the big yellow dessert banana we are familiar with — the Cavendish — but it represents only 10% of the world production of bananas and its cousin, plantain. Unfortunately, almost all the research carried out on these crops has focused on the export banana, in an industrial context.

The remaining 90% of the world production of more than 68 million tonnes of bananas and plantain (a starchy cooking banana) are grown by subsistence farmers and are consumed locally. Rich in carbohydrates, phosphorus, calcium, and potassium as well as vitamin C, bananas are a starchy staple for millions of people in developing countries. Canadians, for instance, eat an average of one banana a week, but many Africans eat 20. Furthermore, the cost of producing bananas

is lower than that of virtually any other staple food crop grown in the humid tropics.

But small banana growers are being hard hit by serious diseases that threaten to wipe out the crop. One of the worst is black sigatoka (*Mycosphaerella fijiensis*), a fungus that destroys the leaves of both banana and plantain. Originally detected in the South Pacific, it has spread with devastating results throughout much of Latin America and now threatens Africa. Since its appearance in Honduras in 1972, for example, it has now spread as far south as Ecuador and is threatening Venezuela's most important plantain-producing areas. The disease has claimed thousands of tonnes of bananas and plantains, endangering the livelihood of subsistence growers. In a four-year span in the 1980s, for instance, Costa Rica experienced an 80% drop in plantain exports.

The only effective protection against black sigatoka is frequent aerial spraying of fungicide, a process too expensive for small-scale growers. Annual control costs are estimated at US $800–1500 a hectare, a price only multinational, banana-exporting companies can afford. Moreover, fungicides are dangerous to the environment and destroy soil microorganisms that could play a role in increasing crop productivity.

Concern over the fungal disease and the lack of organized research into banana and plantain led in 1984 to the foundation of the International Network for the Improvement of Banana and Plantain (INIBAP), headquartered in Montpellier, France, to coordinate the work of scientists around the world. To date, the program has succeeded in establishing collections of banana varieties in many parts of the world. Test tube methods have also been developed that enable researchers to grow disease-free plants for research and multiplication.

Finding a cure for black sigatoka is not easy. There are thousands of banana varieties, and their culture varies tremendously from region to region. Other diseases and pests also take their toll. Panama disease, for example, wiped out the standard Gros Michel export banana in the early part of this century. The Cavendish variety saved the industry, but it is now susceptible to a new strain of the fungus.

Since 1987, INIBAP's Latin American and Caribbean network has been particularly active. Scientists first focused their efforts on developing resistant strains of plantain. After producing more than 15,000 plants through chemical mutation techniques, two strains have shown partial resistance to the disease. Efforts are also being made to control the disease through the development of new, more effective fungicides, better application techniques, and the early detection of the disease's spread.

Fish on the menu

Compared with agricultural production, the contribution of marine fish to world food supplies is quite small; seafood amounts to

only 2% of the world's diet and provides 14% of the animal protein. It is vital for coastal populations in developing countries, however, and for a few developed countries such as Japan and Iceland.

Although developed countries led in world fish capture, there has been a growing harvest in developing countries, particularly in Asia — six of the top 11 fish-producing nations are now in the South. Developing countries are, therefore, also taking a larger part of international trade in fish and fish products. In 1987, FAO described fisheries as "one of the few bright spots in world agricultural trade," citing an expansion of 50% in volume and about 75% in dollar terms since the start of the decade. The developing countries' share of that trade had increased to 44%, almost doubling its volume and revenue.

Although this might bode well for some developing countries' economies, it does not necessarily do so for their environment, resources, or populations. Chile, for example, is the world's third largest producer. More than 90% of its fish production is used to make fish meal, a basic ingredient of animal feeds. Fishing is the country's third largest export earner, but environmentalists note that some of the more valuable species, such as swordfish, are already exhausted. In 1986, half of the crab sold was below minimum size. Wastes from fish meal processing plants foul local waters, killing off the flora and fauna.

The depletion of Chile's coastal resource is repeated elsewhere. FAO estimates that we have already reached a global harvest of marine food approaching 90% of the total 100 million tonnes possible, if the resource is to be self-regenerating. In 1986, the marine catch totalled 84 million tonnes. But this figure does not include the estimated 24 million tonnes caught by artisanal fishermen for local consumption. If that estimate is correct, we have already surpassed the maximum sustainable yield.

The pressure on marine resources is not about to let up; fisheries authorities from a number of Latin American countries intend to increase the current rate of local consumption of marine food from 5 to 15 kg per capita yearly, without decreasing the current level of exports. This will require either an increase in production of some 30% by the end of the decade or better utilization of fish now being caught. As many as 20 million tonnes of edible fish are, in fact, dumped into the waters of the world' poorest countries by shrimp trawlers. An IDRC-supported project in Guyana in the late 1970s, for example, showed that this otherwise waste fish could be made into products ranging from fresh fillets to smoked fish sausages. By 1980, a pilot plant was processing over 20 tonnes of fish a month and was supplying fresh and frozen fish to local markets.

The development of small-scale processing plants could help make more rational use of the fisheries resource in many regions while improving the nutrition and incomes of local populations. Artisanal fisheries are often excluded from official catch totals because there is no routine registration of landings from village fishermen or small independent operations. But in the late 1980s, FAO estimated that between 8

and 10 million artisanal fishermen worldwide harvested some 24 million tonnes of fish and shellfish a year for local consumption. It further calculated that one seagoing fisherman provided work for two to three workers onshore, thus raising the number of people involved in small-scale fisheries to 25 million. In turn, these additional workers supported families of at least 100 million people.

In Chile, artisanal fisheries provide more than 90% of the seafood consumed by the local population as well as a good percentage of export commodities. Chile's artisanal fishermen generated $336 million in 1988, 40% of the country's revenues from fisheries. Recognizing their importance and the need to encourage cultivating rather than simply harvesting of the sea, IDRC has been promoting an integrated approach to the problems of artisanal fisheries. This led in the mid-1980s to the development of an Integrated Coastal Development model proposing a multidisciplinary approach to the development of coastal communities. Projects that have followed include the introduction of new preservation and processing techniques and the establishment of processing plants for local markets in Colombia, Brazil, and Peru. A regional network was put into place to coordinate the projects and facilitate the exchange of information.

Where's the beef?

World meat output is overwhelmingly concentrated in the OECD countries, with the US accounting for a third of the region's 70 million tonnes in 1988. China at 25 million tonnes was the world's second largest producer, with the USSR third at 19 million. No other single country accounted for more than 5.5 million tonnes. Canada's share, for instance, was 2.6 million tonnes.

In terms of the economics of animal production, to produce one kilogram of grainfed beef, for instance, requires close to 8–10 kg of feed grain. Pigs are more efficient, requiring only about 4 kg of grain; chickens do better still, about a two-to-one ratio.

North Americans are the world's leading consumers of both meat and grains; we consume about 800 kg of grain a year, mostly as meat. Livestock provide us with about three-quarters of our calories; cereals provide one-quarter. In the South, the proportions are roughly reversed. Interestingly, in the 1980s, the US became the world's largest meat importer. Most of that beef came from Latin America.

Meat production is increasing rapidly in the South, however, in response both to increased population and to increased demand. But, to date, developing countries are not very efficient in their meat production systems. Africa, Asia, and Latin America have two-thirds of the world's cattle but one only-third of the meat; they have more than half the world's dairy cows, hens, and pigs, but produce only one-quarter of the world's milk, and a little more than one-third of the eggs and pork.

One of the main reasons for low productivity is the lack of feed

supplements, particularly in arid and semi-arid regions. The use of agricultural by-products as a feed supplement may solve this problem: rice, maize, sugarcane, and cotton "wastes" in Egypt, for example; coffee pulp in Guatemala; cassava in Thailand. Such feeds do not divert grains from human use.

Even more promising perhaps is the improvement of pastures by the introduction of better forage species. In recent years, tree-cropping systems as a source of feed for sheep and goats have been attracting international research attention. In South and Southeast Asia, for instance, about 20 million hectares of land are under permanent tree crops such as coconut; small ruminants can graze on natural vegetation under the trees, making more efficient use of the land.

Because small ruminants require less capital investment than large ruminants and have more flexible feed requirements, they are a particularly valuable resource for small-scale farmers and the landless. They may hold the key to meeting the South's growing demand for meat.

A chemical feast

The phenomenal increases in cereal production in the 1970s, and sustained yields since, were bought at a price — the ever-growing use of synthetic fertilizers and applications of pesticides. The wisdom of those practices is increasingly being challenged.

Consider the following:

- In the early 1980s, almost half the coffee imported from Latin America by the US contained chemical residues.
- At the same time, beef shipments were sometimes stopped because they harboured several times more DDT than was permitted by US domestic regulations. The DDT, prohibited in many countries as long ago as 1972, was used as a spray against cattle diseases.
- In 1990, European consumer testing found that 41 out of 44 brands of chocolate bars contained pesticide residues; 10 of the 41 contained lindane, banned in agriculture for close to 20 years. The levels indicated that contamination could not be blamed on past applications, but that the pesticide must have been used in plantations and to treat the cocoa beans during storage and shipping. A number of those brands of chocolate are imported into Canada.
- In 1986, the US General Accounting Office reported to Congress that 6% of the imported food sampled contained illegal pesticide residues. The most likely culprits: bell peppers, broccoli, cantaloupes, cucumbers, green beans, grapes, and tomatoes.

The frequent presence of pesticides in imported foods concerns

both North and South. Although developing countries are encouraged by the availability of export markets to improve their processing standards, they often have difficulty meeting the North's high food standards, as set out in the Codex Alimentarius to facilitate world trade in foods as well as protect consumers' health. Some critics argue that these standards are impossibly strict and cannot be met. For their part, northern consumer groups are adamant that standards should not be lowered. Pesticides are only part of the problem; natural toxins, such as those produced by *Salmonella* in fish products, and aflatoxins, in grains, are also often detected.

On a per hectare basis, the heaviest user of fertilizers in the world is Singapore, perhaps not surprising for a city state that is attempting to meet some of its own food needs. Globally, the smaller, more crowded countries use the most fertilizer to get the most out of their limited arable land: the Netherlands, Ireland, New Zealand, West Germany, Switzerland, and the U.K.

The inverse is also true — big countries like Australia and Canada use less fertilizer per hectare, as do poor countries. In 1988, three countries used fewer than 10 kg of fertilizers per hectare: Botswana, Guinea, and Niger.

The use of pesticides is more difficult to document. In 1988, the US produced $8 billion worth of pesticides, of which 40% were exported, chiefly to developing countries. As much as a quarter of the export was made up of chemicals whose use is severely restricted or banned at home. Some of these products, of course, were used to treat produce grown for northern markets. Worldwide sales of pesticides are estimated to have been about US$20 billion.

It is difficult to assess the benefits of pesticides in agriculture because their widespread application coincided with that of other inputs such as fertilizers, mechanization, irrigation, and high-yielding crop varieties. It would appear, however, that pesticides have had a positive effect on crop yields. But overuse has started to erode the original benefits; every kilogram of DDT sprayed on cottonfields in Central America, for instance, has resulted in an estimated 105 extra cases of malaria following the appearance of resistant strains of mosquitoes not targeted by the pesticide. At least 420 pests worldwide have now developed resistance to one pesticide or another. Scientists have warned that unless chemicals are used more selectively, we could find ourselves without pesticides to control important pests in the future.

Many pesticides are used purely for cosmetic purposes, to satisfy the North's appetite for "perfect" produce. The Washington-based Center for Science in the Public Interest reports that two-thirds of pesticides used on California tomatoes, for example, are to limit cosmetic damage, even though the fruit is destined to be crushed and made into sauce. More than a third of pesticides used on oranges are also for cosmetic purposes. For growers, the return is clear — perfect-looking oranges command twice the price of those with scarred rinds.

Defining hunger

There are two types of hunger: famine and endemic deprivation. The first is violent but temporary, whereas the second is much more persistent, forcing people to live in a chronic state of undernourishment. Endemic deprivation, a matter of insufficient food intake, is also usually more widespread.

As Professor Amartya Sen points out, India has been free of famine since 1943 when the Bengal famine killed nearly 3 million people. But as many as one-quarter of the rural population still suffers from persistent undernourishment and the resulting chronic ailments. China, on the other hand, no longer suffers from chronic malnutrition yet suffered the largest famine in recorded history in the late 1950s. Some countries, such as those south of the Sahara, experience both famine and endemic deprivation.

Famine, as Prof. Sen explained during the Fourth Annual Arturo Tanco Memorial Lecture in August 1990, is initiated by severe loss of entitlements of one or more occupation groups, depriving them of the opportunity to command and consume food. The causes can be many: drought, a sudden rise in prices, a decline in food production, loss of gainful employment, etc.

According to current estimates, some 15–25% of pesticide use is in developing countries, mainly on cash crops, including rice, which is both a staple and an export crop. Along with chemical fertilizers, they were part of the package of inputs promoted to boost production during the Green Revolution. The increased use in some developing countries has been nothing short of phenomenal; India, for instance, applied about 2,000 tonnes of pesticides annually in the 1950s. By the mid-1980s, it was applying more than 80,000 tonnes.

In developing countries, imports of fertilizers and pesticides are often heavily subsidized by governments, and international aid subsidies are increasingly used to purchase them. The low price this affords encourages use and discourages farmers from using alternate methods of pest control. When they are used on large estates, the subsidies obviously benefit large-scale farmers. But, says Dr Gilles Forget, of IDRC's Health Sciences Division, the effects of pesticide use — contaminated water supplies, residues in food, etc. — affect everyone. Organochlorine residues have been reported in multiple foodstuffs in developing countries, including red meat, poultry, game, and vegetables in Nigeria; eggs in Kenya; and potatoes in Egypt. They have also been repeatedly measured in human milk all over the globe. The levels measured in Third World countries suggest that nursing infants are often ingesting residues many times over the Acceptable Daily Intakes (ADI) proposed by the FAO.

Pesticide poisonings are becoming alarmingly common. In 1990, WHO reported that "the estimated 3 million cases of acute, severe poisonings may be matched by a greater number of unreported, but mild, intoxications and acute conditions such as dermatitis." Deaths are numbered at about 20,000 annually. But, although industrialized countries

are not exempt — an estimated 300,000 US farm workers suffer pesticide poisoning each year — developing countries are hardest hit. IDRC-supported research into the causes of poisonings has pinpointed a number of causes: untrained and illiterate farm workers who use the products liberally, handling the chemicals without protection; defective and ill-designed sprayers; improper packaging and labelling of chemicals; improper storage of chemicals that results in the contamination of the air, food, and drinking water; the reuse of empty containers for domestic purposes, such as storing milk, water, and food; a shortage of medical personnel and facilities to diagnose and treat cases of poisonings; and suicide.

According to Dr Forget, the actual number may be grossly underestimated. In the Central Luzon province of the Philippines, for example, researchers found that the high number of deaths attributed to strokes could in fact have been due to pesticide poisonings. New syndromes have also appeared, leading to death weeks after treatment for acute poisoning and release from hospital.

Even pesticides thought to be of low toxicity are now being implicated. An IDRC-supported study in China, for example, revealed severe cases of pyrethroid intoxication in cottonfield workers. Pyrethroids, originally isolated from chrysanthemums, had been widely regarded as relatively safe for nontarget organisms, specifically humans.

Because of the lack of stringent regulations in many Third World countries, or of the means to enforce them, pesticides banned in industrialized countries because of their high toxicity or retention in the environment are still widely used. According to Dr Forget, governments often base their import decisions solely on toxicity information submitted by the exporters themselves.

The problems point to the need for better management of pesticides and their more rational use worldwide. The growing adoption of Integrated Pest Management techniques, discussed later in this booklet, is one approach. The international community could assist; a number of industrialized countries, including Canada, have recently undertaken to review their process of pesticide registration, for example. These experiences could form the basis for similar reviews or the establishment of up-to-date regulations in developing countries. Moreover, FAO has published a voluntary code of conduct for pesticide manufacturers that could be made effective in countries where other regulations are difficult to implement. IDRC is in the process of initiating an international dialogue to encourage understanding and resolution of pesticide-related problems in developing countries.

The crops that are most important to the South are the most threatened by pests, diseases, and environmental degradation. That threat looms ever larger for both North and South as productivity decreases on the world's croplands and we come up against the limits of the past decades' technologies. The next chapter looks at those limits and explores novel ways of sustaining food production in the future.

Tomorrow's Food

When the first farmer reaped his first harvest in about 8000 B.C., the Earth's population was around 4 million. Today, that many people are born every 10 days. At that rate, says Professor Robert E. Rhoades, former senior anthropologist at the International Potato Centre (CIP), we will have to grow as much food in the first two decades of the new century as was produced over the past 10,000 years.

But growth in world food production is losing momentum. In May 1989, the World Food Council reported that it had been steadily declining in the Third World's 69 lowest-income countries. To keep up with population growth, estimated to increase by one billion people this decade, food output needs to increase by 40% in the 1990s. African farmers will need to triple their production. But environmental degradation and climate change — problems to which all nations contribute — are threatening the very planet on which we depend.

Last year, "The Global Research Agenda: A South–North Perspective," the first in this IDRC publication series of opinion documents on world issues, clearly showed how global problems are creating an indisputable argument for greater equity, how the industrialized world needs the cooperation of the developing world just as much as the developing world needs the industrialized world's assistance. Nowhere is this truer than in the area of agricultural production and food supplies.

The euphoria of the 1970s over the boundless yields that could be obtained by applying enough technology, enough fertilizer, enough pesticides, have died down and the consequences of these admittedly well-intentioned programs are coming home to roost. Many believe that any further gains — indeed simply sustaining what has been gained to date — will come not from technological strides, but from a better use of inputs, natural farming methods, and increased production from relatively unexplored areas such as agroforestry. One thing is certain, meeting this challenge will require the combined efforts of agricultural scientists, technologists, policymakers, family planners, and farmers the world over.

In this section, we look first at the constraints to expanding food production by conventional means in both North and South and then we will examine some novel approaches that hold much promise for the future.

Earthly limits

In 1987, the report of the World Commission on Environment and Development — known as the Brundtland Commission after its Chair, Prime Minister of Norway, Gro Harlem Brundtland — succinctly described the state of the planet. "The Earth is one but the world is not," it began, and went on to explain how our common future was "threatened both by poverty so dire that survival required scratching out a living from marginal lands, thereby destroying the basis of future welfare, and by wealth so great that it pilfered and plundered the land simply to sustain itself, thereby intensifying land use problems for the poor."

The prescription put forth by the Commission, "sustainable development," soon became the rallying cry of scientists and politicians alike. But not everyone agrees on what it means or how to achieve it. Agricultural systems may be sustainable if production can be maintained at current levels. But as the Technical Advisory Committee of the Consultative Group on International Agricultural Research (CGIAR), points out, sustainability is not a static concept: it is dynamic and must reflect the changing needs of a steadily increasing global population; it must take into account the complex interactions of physical, biological, and socioeconomic factors at the base of all production systems.

Food production is running up against physical limits. Only about 30% of the world's land is estimated to be cultivable, the rest being too cold, steep, dry, or otherwise unsuitable. Of that, half is actually being farmed, the rest is in pasture or forest. Of the land under cultivation, about half is in developing countries. But, because these countries are home to three-quarters of Earth's population, cropland per capita is very low.

Although it might seem simple to double world food production by plowing now-unused potential lands, future gains will not be that easily achieved. Much of this land is not where food is needed and much has serious limitations: some is covered by dense forest where the fragile soils are unsuitable for agriculture and the forests themselves are important reserves of biodiversity; some is home to serious diseases and insect vectors, such as the tsetse fly carrier of trypanosomiasis; some is too steep, or too dry, to sustain production. According to FAO, the amount of arable land in developing countries will increase by less than 10% this decade. That translates into less land per inhabitant. By 2025, there will be no new, high-quality arable land left to open up. As the Resource Clock in the lobby of IDRC's headquarters in Ottawa relentlessly records, this shortage of new lands is being compounded by the loss each year of millions of hectares to erosion or to nonfarm uses. Most seriously affected are tropical, moist forests, such as the Amazon where forest clearing results in high levels of soil erosion, flooding, nutrient loss, and loss of valuable genetic resources. Flooding of lands, particularly for large-scale hydroelectric projects, and the encroachment of cities onto farmlands also reduce the productive land available.

Soil, a fragile resource

Soil erosion in intensively farmed areas and in developing countries is one of the most serious environmental problems of today and tomorrow. Scientists warn that the productivity of up to one-third of the world's croplands is now being undermined and degradation is increasing as more marginal land is farmed. In developing countries, especially, it is seriously damaging agricultural productivity, shortening the life of dams and irrigation projects, and harming productive wetlands. In many regions, rates of soil loss exceed rates of soil formation at least tenfold and it has been estimated that about 25 billion tonnes of topsoil are being lost from the world's croplands every year.

Soil erosion has many causes: we cultivate steep, marginal lands without adequate terracing; practice inexpert irrigation; allow livestock to overgraze grasslands. We also overwork the soil and eliminate tree cover, whether forests or shelterbelts. The process is expected to accelerate, especially in North and Central Africa, the humid and high altitude areas of Latin America, and much of South Asia. If conservation measures are not adopted, agricultural production in Africa could be 25% lower at the end of the decade than it was in 1975.

Traditional shifting cultivation, practiced for centuries to maintain soil fertility, has begun to deteriorate under high population densities. As the fallow period shortens and the land's vegetative regeneration diminishes, soil erosion and land degradation accelerate. Studies in the US have shown that a loss of 2.5 cm of topsoil there reduced both corn and wheat yields by 6%. According to the Washington-based Worldwatch Institute, applying this to the world as a whole, the loss of 24 billion tonnes of topsoil annually — 2.5 cm on 61 million hectares — could reduce the grain harvest by 9 million tonnes a year.

The remedy for soil sickness may seem unpalatable — longer fallow periods and idling of the most badly eroded lands — but it is essential. In fact, both the former Soviet Union and the US are taking their medicine; what used to be called the Soviet grain area has shrunk by 13% since 1977, and the US adopted a plan in 1986 to reforest 40 million hectares of eroding land. Less severely eroded lands could be treated by implementing crop rotation, alternative tillage practices, mulching, and other soil conservation measures.

Erosion is accelerated by deforestation, which also alters local hydrological cycles by increasing runoff and leads increasingly to severe flooding. Each year, more than 11 million hectares of forests are destroyed, most of them converted to low-grade farmland that is unable to support the farmers who settle it. The rest fall to a growing world of timber trade and a soaring demand for fuelwood. The destruction occurs worldwide.

Among the consequences are a scarcity of firewood, forcing villagers to burn crop residues and animal wastes, thus depriving the soil of essential nutrients. As Brazilian scientists have discovered, it results in

higher temperatures and more drought in the surrounding area. The destruction of Africa's jungles may have caused the Sahara to advance, just as the destruction of the Amazon might spell disaster for large tracts of Brazil.

The limits to water

Irrigation is essential to global food security, but experts consider that it will not boost food supplies as much during the 1990s as it has in past decades. The reasons are many: high costs for new projects, ecological problems, concern over social and environmental effects of dams, regional water scarcities. Moreover, past projects are suffering from siltation and may become inoperational.

One-third of the world's harvests today come from the 15% of the world's croplands that are irrigated. Some countries depend on such land for much of their domestic food production. In Egypt, for instance, 100% of cropland is irrigated. It is unlikely that the expansion of irrigation will continue at the rate it has during past decades. Lending for such projects by international donors has declined sharply, whereas the cost of new projects — and cost of the energy needed to operate the systems — has risen sharply. The Worldwatch Institute quotes capital costs of about US$1,500 a hectare in China, up to US$4,000 a hectare in India, and a staggering US$10,000 a hectare in Mexico. In Africa, where roads and other infrastructure must accompany new projects, costs can be as high as $20,000 a hectare. Few crops make this kind of investment economical.

Irrigation's future contribution to world food supply will need to come more from improving existing systems than from expansion. Experts point to the loss of water through unlined canals (loss resulting from uneven application or inappropriate timing) and lack of maintenance that leads to siltation in channels and salt build-up in the soil. Some form of upgrading is required on an estimated 60% of the world's total irrigated areas.

Poor water management also degrades the land, sometimes forcing it to be retired completely. More than 20% of the world's irrigated land is estimated to be damaged by salinization. In parts of the world, including in the US, water pumping for irrigation exceeds the aquifer's rate of recharge. Lands watered unsustainably will eventually have to be taken out of production unless rates are significantly reduced.

Experts warn that securing water to meet the world's growing food needs will not be easy and point to the need for a more diverse approach to watering crops. One avenue is the improvement of irrigation efficiency through measures such as drip irrigation, that saves water and reduces salt build-up due to evaporation; the levelling of fields so that water gets distributed evenly; and monitoring soil moisture so that fields are irrigated only when necessary. Another avenue is the application of older technologies, such as mulching to cut losses from

evaporation, check dams of earth and stone to capture runoff from hillsides, and rainwater reservoirs. As the Worldwatch Institute reports, if farmers are involved in the planning and management of irrigation projects, canals and other infrastructure function better, a larger part of the project area gets irrigated and yields increase as a result.

Cold comfort in a warmer future

Much has been written about pollution that results in acid rain and in increased ground ozone levels, both of which reduce crop yields. Also serious is global warming. It is now clear that poor countries are catching up with the rich when it comes to producing greenhouse gases; according to the Washington-based World Resources Institute, Brazil, China, and India now rank as the biggest global warmers after the US and the former USSR. Current estimates predict a global warming of between 2°C and 6°C before 2100.

The United Nations Environment Programme (UNEP) warns that climate change is expected to cause enormous disruptions in patterns of food production. As temperatures rise and weather patterns alter, rainfall patterns will shift and many water supplies will diminish. Some parts of the planet will become too hot or too dry to support crops, whereas others will experience large boosts in productive capacity.

Some of the predictions include:

- Most of the world's large food producers will suffer significant reductions in both crop yields and livestock production. Continental interiors, the bread baskets of North America and the former Soviet Union, might suffer drier conditions, adversely affecting their ability to produce food for the world markets. This could mean that import-dependent countries could be seriously affected and starvation could increase as world trade in agricultural commodities might decline dramatically. Significant reductions in yields are also expected in Western Australia, the Argentine Pampas, and Southern Africa, as well as in mountain regions of Southwest Asia, the Indian sub-continent, and parts of Southeast Asia.
- A rise in sea level of between 8 and 29 centimetres by 2030 may threaten fertile delta regions including vast tracts of land in Bangladesh, Egypt, Indonesia, China, and India.
- Higher latitudes could warm by as many as 9°C, allowing land previously too cold to be farmed. But geologists warn that the soils at this latitude are simply too poor for current intensive methods of agriculture and that, even with abundant rainfall, it could take thousands of years of soil formation before they could sustain crops.

- Increased carbon dioxide in the atmosphere could have a fertilizing effect on plants, increasing yields for at least a few seasons.
- Large insect populations and increases in plant diseases may contribute to drops in crop yields.
- Marine ecosystems may be disrupted; the flooding of coastal wetlands may mean the loss of an essential nursery for many fish, shrimp, and bird species. This could significantly reduce the quantities of seafood available for human consumption.
- As the sea moves inland, groundwater supplies in many parts of the world could become contaminated and previously fertile land poisoned by salinity.

More flexible patterns of agricultural production and new farming techniques will obviously be needed to cope with these climatic fluctuations. Although no country will be immune from changes, developing countries that depend on natural resources, such as crops and grazing lands, forests, fisheries, and monsoon patterns, will be most seriously affected. These are the countries least able to adapt because of a shortage of financial and technical resources. Considerable education and technical assistance will be needed to assist these countries, further emphasizing the interdependence of the futures of both North and South.

Rethinking the Green Revolution

Some 25 years after it began, the Green Revolution remains a landmark in international agricultural development, a tribute to humanity's ability to overcome seemingly unsurmountable physical constraints and ward off famine. The new varieties spread quickly through Asia and Latin America. By the mid-1980s, about half the wheat area and nearly 60% of the rice area of all developing countries had been sown to high-yielding varieties.

Harvests rose accordingly: the amount of rice and wheat grown in developing countries increased by 75% between 1965 and 1980, whereas the area devoted to these crops increased by only 20%. The ability to harvest two, even three, crops a year contributed to these increases. There is no doubt that this rapid expansion of the food supply staved off hunger and saved the lives of tens of millions of people.

The North also profited from the Green Revolution, because as production increased in developing countries, so did incomes. A large part of the extra money went to buy food; from the early 1960s to the mid-1980s, the 24 developing countries with the fastest growth rates in production of food staples (more than 4% a year) increased their net imports of food staples at an annual rate of nearly 10%. Cereals from industrialized countries constituted a large part of the food imported.

Not everyone benefited equally from the Green Revolution. The new seeds, fertilizers, and pesticides that initially boosted the crop yields of Asian and Latin American farmers who had access to irrigation and markets did little for subsistence farmers who worked rainfed marginal lands. Not only did their yields not increase, but they faced greater competition from those who adopted the new technologies. In the years since, most small-scale farmers in regions suited to the new varieties have followed the lead of large-scale farmers. But not all regions are suitable. Thus, the Green Revolution has contributed to changes in regional income distribution in some countries. African farmers, in particular, were largely bypassed. By 1986, only 1% of Africa's grain fields were planted to the improved varieties of rice and maize.

High-yielding varieties are still spreading, and ever newer varieties are performing better, with fewer costly inputs. But there is a price attached to every success story, and some of it is now being paid. A major price is the actual loss of land races (i.e., traditional varieties). India's Punjab, for example, flourished with the introduction of semi-dwarf rice varieties and the "appropriate technology packages" in the late 1960s. Now, farmers are finding that the exponential growth in grain production has been accompanied by a similar growth in the range and intensity of insect and disease attacks on their crops. At last count the new varieties were affected by 40 insect pests and a dozen diseases, many of them serious enough to cause severe losses. Hitherto, only five insect pests and three diseases affected rice in the region.

There has also been a levelling off of increases as the biological limits of the new hybrid strains are reached. In the Chiang Mai Valley of Thailand, for example, rice yields increased from 4 to 7 tonnes per hectare during the 1970s. Today, yields have slipped back to original levels, despite continued high inputs of fertilizers.

This mixed success is to be expected. The Green Revolution was a significant contribution to increasing food availability. It also resulted in the development of the unique CGIAR network of international agricultural research centres (IARCs), described earlier in this report, that has helped increase productivity in both the developed and the developing areas of the world. The IARCs' share of research expenditure is not large in global terms, but it has measurable effects on world agriculture.

That research establishment is now turning its attention to neglected peoples and crops on arid marginal lands and to farming techniques that are environmentally sound. Although the greater part of world agricultural research remains concentrated in developed countries, investments in Third World research have increased substantially.

Preserving diversity

If nothing else, the Green Revolution demonstrated just how far the economies of developing countries could improve and how substantially food production could increase with the proper scientific and political support. Similar gains could be made in countries left behind, but the task will be much more complex. Scientists will need to develop high-yielding varieties of crops that will permit farmers to intensify production sufficiently on fertile lands so that more fragile environments are protected. More environmentally sound land-use patterns will need to be introduced. New varieties of staple crops important to those regions will need to be developed.

The enormous strides made during the Green Revolution were possible because there existed a huge backlog of improved wheats and rices in Japan and North America, varieties whose pedigrees predated World War II. With the exception of maize and beans, similar success with the staple grain and root crops of Africa will be more difficult because these crops grow under widely diverse environments and have no comparable history of improvement.

Efforts to raise the productivity of staple crops depend on gathering a wide range of land races, crop relatives, and wild plants for breeding. Collecting and storing crop germplasm, an important program at all the international centres, is coordinated by one of the CGIAR centres, the International Board for Plant Genetic Resources (IBPGR).

For most major food crops, germplasm collections of modern and traditional crop varieties are broad. In 1985, there were an estimated 400,000 wheat samples in major gene banks, representing 60% of the wild species and 95% of the traditional varieties. Not so for other crops. Although the traditional varieties were well represented, few of the wild relatives had been located; only 10% in the case of rice, barley, and sorghum, and 1% of cowpeas.

The worry is that both traditional varieties and their wild crop relatives are being lost as modern varieties and monocultures replace traditional farming methods, forests are destroyed, cities spread, lands are flooded by water-control projects. It is estimated that a quarter of the world's 250,000 plant species may vanish in the next 50 years. The situation is expected to get worse in the future if global climatic change occurs and leads to major shifts in plant ecosystems.

The depletion of plant species has serious consequences for both North and South. As Brian Belcher from IDRC explains: "This germplasm is needed to produce new varieties of crops for the future. This is particularly important in the face of the increasing need to develop crop varieties that are able to withstand new diseases and pest epidemics. The ability to produce new crop varieties able to withstand changes in the global environment may be crucial to humanity's survival."

Modern agriculture is very vulnerable; a few varieties of major crops feed most of the world and many are genetically similar. The con-

sequences were obvious in 1970 when a strange new pest threatened 80% of US corn fields, reducing national crop yields by 15%. Since then, genetic uniformity has increased; just four varieties produce 75% of the wheat grown on Canada's prairies, for example, and half of the land is covered by just one variety, Neepawa.

This uniformity is spreading to the South. During the past 50 years in India, farmers may have planted as many as 30,000 different varieties of rice. Authors Cary Fowler and Pat Mooney, past winners of the Right Livelihood Award, claim that by 2005 three-quarters of all India's rice fields will be planted to only 10 varieties. As others have pointed out, a large proportion of high-yielding rice varieties grown throughout the world contain the same maternal parent, *Deo-gee-woo-gen*, an Indonesian variety. Now breeders warn that many traditional rice varieties are becoming extinct.

The genetic wellspring of the world's agriculture is located largely in the tropics and the southern hemisphere. The Third World still has tens of thousands of wild varieties of these and other crops with genetic characteristics that could improve current crops and that will be needed to adapt current varieties to future conditions. The Rio Palenque Research Station in the wet coastal forest of Ecuador, for example, supports more than 1,000 plant species on 170 hectares, the highest recorded concentration of plant diversity on Earth.

The right to use these resources has been the subject of heated controversy as the Third World demanded that it be compensated for the use of its genetic wealth while the industrialized countries refused. These conflicts froze many international efforts to develop a concerted global approach that could provide short- and long-term food security for everyone.

Progress is now being made. In August 1991, following three years of negotiations, an international group of key experts from conflicting sectors, ranging from multinationals and farmers' organizations to Third World scientists and politicians, developed a concrete plan of action for adoption by governments at the 1992 UN Conference on Environment and Development (UNCED/the Earth Summit) held in Brazil. The final report of the Keystone International Dialogue Series on Plant Genetic Resources outlines the funding and institutional structures required to conserve and utilize the world's plant genetic resources, including the need for a US$1 billion global fund for the period 1993–2000.

Solving the impasse is all the more important now that it has been discovered that many of the seeds and varieties "saved" in cold storage in gene banks have not survived. Conservation will now have to involve "in situ" collections; paying farmers to grow plots of old varieties, in their natural environments.

That kind of program is already under way in Ethiopia where farmers are being paid the difference between what they would earn from a high-yielding variety and what they earn by maintaining a plot of

an old one. Speaking at a meeting on plant genetic resources sponsored by IDRC in late 1990, Dr Melaku Worede, Director of the Plant Genetic Resource Centre in Addis Ababa, explained that drought made the program essential; the resulting crop shortages forced farmers to eat their seeds rather than preserve them. They then planted grain donated from other countries. Scientists soon realized that the most severely affected crops were those planted using the modern, imported seeds. For Dr Worede, ancient seeds are the key to self-reliance in Ethiopia. In 1989, he received the Right Livelihood Award — the "alternate Nobel Prize" — for spearheading the seed rescue operation. But, he warns, North and South do not agree on what is meant by conservation. Northern plant breeders are interested in developing uniform varieties or in introducing certain characteristics into a crop. Third World farmers are more interested in diversity, because they plant different varieties in different plots to make sure something will survive.

Rediscovering agroforestry

Changing world conditions and the seeming roadblock to the continued expansion of the high-technology agricultural practices is leading scientists to reexamine and recognize the ecological and agronomic strengths of traditional practices that have, over centuries, allowed farmers the world over to feed themselves while maintaining soil fertility. Much research is, therefore, devoted today to improving existing farming systems rather than to transforming them entirely.

One of the areas that has attracted attention in the past 15 years is agroforestry, a farming system that combines agricultural and forestry methods for cultivating woody plants and agricultural crops and livestock or both on the same land to increase the total productivity of the plot.

A living resource, trees provide seeds and fruit; on farms, their leaves are used as fodder for livestock; planted as living fences, they keep grazing animals out of crop areas. They serve as windbreaks. Shade trees in pastures and fields help improve the microclimate, making animals and plants more productive. Trees with long tap roots for anchorage and spreading lateral roots bind the soil and prevent erosion. The leaves and branches can be mulched to provide nutrients to growing crops. Mulching also protects the soil and contributes valuable organic matter. Trees are a valuable cash crop; on the Kenya coast, for example, they are sold to cover the costs of contingencies and redeem debts.

Traditional agricultural systems the world over probably always included trees. The challenge to research is to revive old methods, improve them, adapt them to different conditions, and develop new methods. That is the goal of work carried out by many agricultural research stations around the world, coordinated by the International

Council for Research in Agroforestry (ICRAF), based in Nairobi, Kenya. IDRC helped set up ICRAF in 1977.

One of the potentially most important agroforestry systems for Africa is alley cropping, a form of intercropping in which food crops are grown between regularly pruned rows of fast-growing, nitrogen-fixing trees and shrubs. Research carried out at IITA in Nigeria, for example, showed that permanent hedgerows of leguminous trees like leucaena and gliricidia could improve yields of food crops planted between them. The trees are pruned regularly, and the clippings are used as mulch or green manure, or even as animal fodder. Furthermore, the use of legumes, such as the fast-growing leucaena, actually increases the nitrogen available in the soil. On sloping land, the hedgerows help to prevent erosion.

Tested at IITA with IDRC support, alley cropping was found to increase organic matter, usable nutrients, and moisture levels of soil, thus allowing continuous cropping with improved crop yields, without additional inputs. The system, in fact, offers the benefits of the traditional fallow period without taking the land out of production and sustains land productivity for longer periods.

Leguminous trees also hold promise for other regions. In Costa Rica, for example, researchers have identified species of leguminous trees that can be used as living fences and stakes for pepper and vanilla plants, shade for coffee bushes, and animal feed. With IDRC support, the promising species are now being multiplied for testing in farmers' fields.

Agroforestry techniques are not just for developing countries. According to the University of Guelph, the province of Ontario could gain by planting red oak and black walnut in corn fields. Although the large trees would reduce crop yields by about 7%, they could save the $100 million spent annually to import red oak from the US Walnut is also a valuable wood and the nut harvest could yield about $25,000 a year from 40 acres. The trees would also improve the soil and reduce the need for fertilizers.

Intercropping does not have to involve trees. Legume-based crop rotations and traditional intercropping systems use organic materials and nutrients much more efficiently than monocultural systems. It has been found, for instance, that if farmers grow maize after the cowpea crop, the yield is more than double that when maize follows maize. Overall, intercropping provides a higher and more stable output and conserves the soil better. It provides a denser vegetation cover, thus reducing erosion and increasing the infiltration of water. It also helps keep weeds down and slows the spread of pests and diseases while providing more stable yields.

Asia's rice and fish combo

The ancient practice of growing rice and fish together is making a comeback in Indonesia, Thailand, and the Philippines. It results in higher rice production, reduces the needs for pesticides, improves the soil, and provides subsistence farmers with a source of high-quality protein.

Rice–fish is an integrated farming system with a long history. Chinese farmers have been raising fish in flooded rice fields for 2000 years, maybe longer. Originally, wild fish bred naturally in the paddies and were harvested as needed. Over time, husbandry techniques evolved in many countries. But with increased population pressures, the advent of high-yielding rice varieties and concomitant use of chemical fertilizers and pesticides, the practice was abandoned.

In the past decade, however, the need for more efficient and sustainable farming systems has led to renewed interest in rice–fish farming among farmers, researchers, and policymakers. The synergistic effects of rice and fish in the same field exemplify the advantages of an integrated approach to farming. The key benefits are that fish recycle nutrients and reduce both insect and weed populations. In Indonesia, rice–fish culture with carp increased yields of commonly grown rice varieties.

The technique is quite simple. It consists essentially of digging a small pond or trench at one end of the paddy and erecting banks to retain water. The banks around the fields can be used to grow vegetables. Constraints are the availability of water and water quality — chemicals commonly used to boost rice yields have killed both fish and their foods in parts of Indonesia. Recognizing this, the Indonesian government recently reduced many of the import subsidies on pesticides.

Several Canadian and Asian government and nongovernmental organizations are involved in the research. Rice–fish farming is one of many rice-based farming systems in Asia that promises to increase the availability of food in a sustainable way.

Managing pests

It is now widely accepted that the chemical pesticides required to sustain yields are a mixed blessing; they have contributed to increasing the food supply, but have also contributed to environmental contamination, illness, and death.

There are alternatives. The principle that underlies most efforts to reduce pesticide use is called Integrated Pest Management (IPM). It sees crops as an ecosystem within which many natural forces affecting pests and weeds interact. IPM draws on biological controls, cultural practices, genetic manipulations, and judicious use of chemicals to produce the most food, at the least cost, and with the least risk to health and the environment.

IPM and biological methods of pest control can provide long-lasting solutions. In Sweden, for example, farmers have reduced pesticide use by almost 50% with no reduction in food yields by using efficient spraying equipment, fewer treatments, low-dose pesticides, integrated pest management, and organic farming methods. The Dutch and Danish governments have launched similar programs.

Indonesia adopted IPM as the national pest-control strategy for rice in the late 1980s and banned 56 of 57 previously approved pesticides. Farmers were trained in IPM techniques; as a result, they use 80% fewer pesticides than before and have increased crop yields. They have also cut their costs drastically while the government is saving the $120 million previously spent on pesticide subsidies. In 1991, farmers' profits increased by more than US$60 per hectare. By 1994, all of Indonesia's farmers will have been trained. Farmers practicing IPM in Bangladesh, Thailand, and the Philippines have reported similar success. But, despite such results, it is estimated that only 3.7% of Asia's rice farmers now practice IPM.

Biological control methods are one component of IPM. They are also often a weapon of choice, used on their own. The world's most extensive effort at biological control is that under way in Africa to control the cassava mealybug and the green spidermite that, together, have reduced yields by an average of one-third across Africa's cassava belt. The program is being carried out by IITA in partnership with national projects across the continent.

The green mite (*Mononychellus tanajoa Bondar*) was inadvertently introduced to Africa from South America in the early 1970s and quickly spread over large parts of the continent. In 1974, the Commonwealth Institute of Biological Control (CIBC) in Trinidad — a unit of the Commonwealth Agricultural Bureaux — sought IDRC's assistance to find the pest's natural enemies. Because the pest is a native of South America, that is where the search for its natural enemies was carried out. In the late 1970s, the most promising mite predator, a small black beetle (*Oligota minuta cam*) was released in East Africa.

At about the same time, a new cassava pest was appearing in Africa, the mealybug *Phenacoccus manihoti*. After a few years of persistent hunting, researchers also found promising predators and parasites of the mealybug in Latin America. After extensive testing, the predatory wasp *Epidinocarsis lopezi* was selected as the most promising; it was then bred and released. World Watch reported in April 1991 that it took eight years to cover about one-third of the infested fields in 24 of the 28 countries.

To monitor the wasp's progress, IITA's Biological Control Program has trained at least 400 people and helped start 15 national, biocontrol programs. To date, the predators have succeeded in reducing losses by more than half. The regional and international research and distribution network set up is now poised to tackle new pests of maize, cowpea, and banana and plantain.

The potential of biological control methods offer numerous examples in both North and South. Tiny parasitic wasps called Trichogramma, for instance, are widely used on China's croplands. They are also used in India, El Salvador, Mexico, the USA, the former USSR, and, experimentally, in Canada to control spruce budworm.

Research under way in all parts of the world could expand the arsenal. *Bacillus thuringiensis* (B.t.), a fast-acting bacterium effective against some caterpillars, has been used to control forestry and agricultural pests for the past 50 years in both industrialized and developing countries. In Canada, B.t. is used extensively against spruce budworm but not against crop pests because the major strains are not effective against the country's major agricultural pests. Egypt faces a similar situation. In 1985, with IDRC support, scientists from both countries set out to identify new strains that would be effective against pests of Egypt's soybeans and groundnut crops and of Canada's canola crop. To date, the collaborative effort has developed ways of keeping the bacillus active for longer periods and of producing large quantities cheaply.

A number of plants also provide safe and effective pesticides; the neem tree, for instance, was used in ancient India to ward off pests in fields and granaries. Neem products are now in commercial production and were recently released for use in the USA. More may become available as a result of research currently under way, such as one program that links researchers from the University of Ottawa, Carleton University, and the University of British Columbia with scientists in Thailand and the Philippines. Their funding comes from IDRC, the Natural Sciences and Engineering Research Council, the Ontario Ministry of Agriculture, CIDA, and Safer Inc., of Victoria B.C. Using information on insecticidal plants provided by farmers, the researchers will isolate and purify the plant pesticides. The aim is to produce effective commercial sprays that are safe for nontarget organisms and cheaper than synthetic pesticides, which many small-scale farmers can ill afford.

IPM programs are necessarily complex and must be designed for the specific pest against which they are targeted, in the environment in which they will be applied. They are not as efficient as chemical control; biological means typically eliminate 75–85% of the pests. But they are usually less costly than chemical controls, and the benefits may be felt for years to come. Industrial countries stand to gain as much as developing countries from an integrated approach to pest management; it reduces input costs, increases yields, protects water supplies from contamination, and it is profitable. A 1987 survey showed that New York apple growers and California almond growers who were using IPM reaped per-hectare profits $528 and $769 greater than nonusers, respectively.

Innovative approaches

The world's concentration on a handful of plants has led to the neglect of minor plant species that may possess equal merit to the world's staple food crops. Growing concern over the eroding gene pool and the recognition that some innovative approaches are needed if we are to succeed in feeding the world's population could lead to a renaissance both of ancient crops and of ancient cropping methods.

The High Andes, in particular, is a treasure trove of foods and agricultural techniques. Archaeologists digging for some of those treasures in the vast areas that were intensively cultivated in prehispanic times have rediscovered technologies that could be profitably exploited today: circular field basins, sunken gardens in areas of high ground water, raised fields in waterlogged areas. On experimental, raised fields, for instance, they found that sustainable potato yields were twice those of the control plots, sometimes much more. When frost destroyed harvests on conventional plots, losses of potatoes, barley, quinoa, and vegetables were minimal on the raised fields. As "Nature" reported in 1990, the raised-field technology requires no imported seed, chemical fertilizers, or expensive machinery.

Ancient Inca crops have also earned new respect. The cereal quinoa (*Chenopodium quinoa*), for instance, was largely wiped out in the High Andes despite its hardiness and impressive nutritional qualities; its protein content of about 14% has a good balance of essential, body-building amino acids, especially lysine. It also contains necessary vitamins.

Serious research to increase quinoa yields and its nutritional qualities began in Bolivia in 1965 with the support of Oxfam and FAO. IDRC joined the efforts in 1976. Today, in Peru, strong efforts are being made to increase quinoa production as a means of reducing costly wheat imports. In Bolivia, the government has gone so far as to pass a law requiring the use of at least 5% quinoa flour in commercially produced breads and pasta. IDRC is continuing to support research in this country to evaluate improved quinoa varieties and introduce the best, along with quinoa-based cropping systems, to highland farmers. In Chile, quinoa is used in feeding programs to improve the nutrition of poor children.

Quinoa is also finding an unlikely home on a few hectares in Manitoba where a local farmer is growing the grain for sale to health food stores. That is currently the crop's main market in the industrial world. The Saskatchewan Research Council is looking at quinoa as a crop that would thrive on the province's highly alkaline soils, enabling the cultivation of a previously underutilized area. Trials have been promising and a marketing program is being introduced.

Ironically, some "new" crops may also be in need of rediscovery. Triticale, hailed in the 1960s and 1970s as the grain of the future, has failed to realize its potential. But the US National Research Council

predicts that the hotter temperatures and more difficult growing conditions of the next century may breathe new life into the cereal. A cross between wheat and rye, triticale was developed at the International Maize and Wheat Improvement Centre (CIMMYT) in Mexico and the University of Manitoba in Canada. The cereal combines the nutritive value of wheat with the ruggedness of rye so that it outperforms wheat in poor soils and extreme climates. Some 115 million hectares of triticale are now grown in 32 countries; it is used mainly to make unleavened breads. The major problems to triticale's widespread acceptance as food is that it does not meet consumers' requirements — dough made from the flour is too sticky to roll out of high speed mixers used in industrial bakeries. CIMMYT researchers have now developed strains for use in leavened breads. Other problems that remain are to diversify the cereal's genetic base and increase its disease resistance.

Just as the world has focused on a handful on plants, so have we concentrated on just nine animal species. That too could change. In Colombia and Venezuela, for example, about 50,000 capybara — 40-kg rodents — are being "farmed" for meat. Because of the rodent's high fertility, capybara yield more meat per hectare than a cattle herd. In Peru, the capybara's smaller cousin, the guinea pig, has traditionally been reared in household production systems; 73% of Lima's population, for instance, consume them. Research under way since 1986 with IDRC support is now improving rearing systems to increase production of the nutritious rodent.

Waste not

In the drive to increase food production, too little attention has been paid to preserving what was already grown. It is estimated that in developing countries, at least 10% of the cereal and legume crop is lost as a result of inefficiencies in the postharvest system, from harvesting through processing and use in the home.

If these losses could be reduced by half, it would be equivalent to an increase in supply of some 48 million tonnes of cereals in 1991 (assuming losses of 10%), a large part of the developing countries' total cereal imports of 79 million tonnes. Similar gains in protein-rich legumes could also be achieved.

The need to preserve what has been called the "hidden harvest" is now becoming clear. The ASEAN nations, for instance, are now recognizing that the food situation in the region can be considerably stabilized if postharvest losses are minimized. In 1989, E.C. consultants lauded the region's efforts in reducing losses, citing the activities being pursued through the Southeast Asia Cooperative Postharvest Research and Development Program. In effect between 1976 and 1986, the program identified and developed solutions to problems ranging from insect and rodent infestation to village milling systems. It was supported

by a consortium of international donors, including CIDA and IDRC. Both Canadian agencies are supporting a subsequent program, the collaborative regional ASEAN Grains Post-Harvest Program that seeks further improvements in the region's cereal and legume postharvest system.

During the 1970s and 1980s, much postharvest activity was aimed at removing bottlenecks identified in the chain from field to table. In Africa and India, for instance, the absence of appropriate dehulling equipment was recognized as a cause for the neglect of sorghum and millet. Although the cereals accounted for 28% of cereal production on the African continent, they were a small part of cereals bought and distributed by official grain-marketing agencies. For the consumer, the daily task of manually dehulling and pulverizing the grains was a constraint to their use. Analysis showed that improving the processing of these crops would lead to increased production. An abrasive-disk dehuller designed by the Prairie Regional Laboratory of Canada's National Research Centre has since been tested with IDRC support and adapted to processing local grains and grain legumes in 17 African countries as well as India.

But as Dr Edward J. Weber, former Associate Director, Post-Production Systems at IDRC points out, there are no quick technological fixes to postharvest losses. Postharvest activities in most developing countries involve a large number of small enterprises that prepare, process, store, distribute, and market food products as well as supply the goods and services as inputs to the production process. These enterprises provide jobs for more than half the industrial labour force in most developing countries. It is important, therefore, to place the activities normally associated with the postharvest and market system in a total food system perspective.

A cassava-processing project at the International Center for Tropical Agriculture (CIAT) in Colombia illustrates the approach and its potential. Supported by IDRC, a team of researchers from CIAT and two Colombian institutions was assembled to attack the many-sided problem of how, and under what conditions, a new product — cassava flour — could be incorporated into the existing wheat flour milling industry and accepted by the baking industry.

The prefeasibility study involved a macroanalysis of the Colombian wheat market and a compilation of information on cassava production, a wheat milling survey, and a baker and consumer survey. A village cooperative processing plant was designed; equipment and storage conditions were evaluated and modified. The bakery product development involved cassava variety and harvest age trials, flour production, optimization of baking procedures, and quality control and acceptability studies. The whole system is now being pilot-tested with a farmers' association, millers, and bakers.

Another IDRC-supported project in Kenya focused on edible oil and protein for animal feed systems. The analysis of the country's total oilcrop production and import and utilization system is leading to

changes in government policy on imports to favour greater local production and processing opportunities.

Efficient postproduction systems are essential to food security, and harvests from improved systems of production can be significantly wasted and underutilized by deficient protection, preservation, product development, and distribution.

Developing countries have described patterns of growth among food-processing industries and their need for supporting research and technical assistance. Donor support has been largely uncoordinated and more directed to particular technologies than to studies of systems, market demand, and consumers' needs.

The early economics of many developed nations were driven by agroindustries during a gradual transition from rural subsistence farming to urban communities increasingly dependent upon safe commercial systems of food processing and distribution. Almost half the developing world's population live in cities, many of several million inhabitants. Dense, rapidly growing urban populations cannot be fed and sustained by field-to-mouth subsistence agriculture; their food safety and security depends upon proficient processing and distributing systems.

Most systems of preservation and transformation are adaptable to large- or small-scale, capital- or labour-intensive processes; they rely upon both highly- and modestly-skilled people. They are well-suited to women in management, production, marketing, sales, administration, and process and product development and control. Because processing is usually best when close to the place of harvest, agroindustries provide rural employment. Their employment is relatively stable, because it is noncyclical.

African and Asian countries reported food industry growth rates from 8 to 12% per year, with relatively small-scale processors representing between 60 and 90% of the total. These industries preserve, transform, and add value to local agricultural products. Preservation prevents wasteful impairment of nutritional quality and economic value. Transformation diversifies utility, offers convenience to consumers, and can favour farm-grown over imported commodities.

Although giving priority emphasis to research to understand better how crop composition and component properties may be influenced by genetic diversity and modified by manipulation, many developing-country industries need technical and other assistance. To suggest how technical efficiency can be progressively improved, more study is needed on the principles and practices of Operations Research, which are methods that use existing resources with the most practical and economic efficiency.

Because of the past emphasis upon technology push and transfer, with less evident concern for consumer need and demand, more market and marketing research is also needed. These subjects are presented in historical perspective and are intended as indicative but not definitive for all people and places. Future postproduction systems R&D should

give more attention to relevant social, economic, and policy issues, particularly as they affect employment opportunities and nutritional and environmental consequences.

Land-based fisheries

Aquaculture is considered a means of vastly improving the total marine fish yield world wide because it can produce much higher yields per unit of area than fishing can. Many valuable commercial species are now farmed, including salmon and trout in North America and Europe. Molluscs are widely cultivated in Western Europe and Japan, and shrimp culture in lagoons is currently one of the fastest growing fishery businesses in Southeast Asia and parts of Latin America. Canada, for instance, imports large quantities of shrimp from both Ecuador and Thailand. But in both these countries, shrimp farming is a major cause of mangrove degradation; 60,000–70,000 hectares of Ecuador's mangroves have been destroyed for shrimp farming, for instance, and two-thirds of the Philippines' mangroves have been lost to aquaculture activities.

Aquaculture does not have to be large-scale, nor does it have to be expensive and destructive. The Chinese have developed aquaculture into a fine art; in the mid-1980s they were producing close to 3 million tonnes of freshwater fish a year out of a global total of 6 million tonnes. Other large producers include India at half a million tonnes and the Philippines at a third of a million tonnes.

One of the main problems with fish farming throughout the world is obtaining an adequate supply of fry to stock ponds. Catching wild fry and fingerlings is time-consuming and expensive, and fish do not reproduce in captivity in an easy and predictable way. Research supported by IDRC is taking a two-pronged approach to solving the problem — improving both the breeding and the breeds.

A breakthrough occurred in 1977 at the Southeast Asian Fisheries Development Center (SEAFDEC) in the Philippines where researchers induced milkfish to breed in captivity using artificial fertilization. Ten years later, Chinese and Canadian researchers succeeded in developing a fish-breeding kit for carp, the most widely cultivated fish in China. The kit contains the necessary amount of synthetic hormones, chemicals, and syringes for fish farmers to give brood fish two quick injections that overcome the breeding problem. A Canadian company, Syndel Labs of Vancouver, started marketing the kit intemationally in 1990. Canadian fish farmers are using it for salmon and trout rearing. The technique has also been used in commercial production of catfish fry in Europe and carp fry production in Poland. The largest sales are in Asia where fish provide the main source of protein in daily diets.

Improving fish breeds is a similarly collaborative effort. Since 1982, IDRC has been helping to develop a network linking aquaculture

genetics projects in Asia with each other and with Dalhousie University in Halifax. The aim is to use modern selection techniques to develop improved varieties of fish. Researchers have succeeded in developing a procedure for estimating the growth rate of fish by measuring the tiny concentric ridges on their scales. The procedure has found application elsewhere; a project in northeastern Thailand, for instance, jointly funded by CIDA and the Thai government, used it to evaluate fish growth conditions in farm ponds and reservoirs. The international team has also found that domesticated fish grow more quickly than their wild counterparts, indicating that aquaculture systems should concentrate on fish bred for the purpose.

Aquaculture projects can include more than just fish. In southern Chile, for example, farmers and fishermen are growing and harvesting mussels that had almost been wiped out in the area due to overharvesting. Research by Chile's Institute of Marine Research started in 1984 with IDRC support. Nineteen family enterprises now participate in growing the much prized seafood on ropes dangling from simple wooden rafts; each raft can produce 10–12 tonnes of mussels a year. The area is now becoming a major supplier of spats — embryonic mussels — to mussel ranchers in other areas. The surrounding countries of Brazil, Colombia, and Peru are studying how Chile's success might be reproduced in their regions.

Shrimp is also a prized aquaculture commodity in both Asia and Latin America. But unless shrimp producers clear ponds of competing and predatory invaders such as eels, sea bass, and tilapia, up to 40% of the crop is lost. In Thailand, the piscicide used is expensive tea seed cake, imported from China. Working in collaboration and with IDRC funding, scientists at Chiang Mai University and the Prince of Songkla University in Thailand, and at the University of British Columbia in Canada, have discovered an inexpensive piscicide in a local plant. The natural piscicide is nontoxic to nontarget organisms and breaks down quickly, leaving no toxic residues in the fish or water. Patents are being applied for the product in both Canada and Thailand and a Thai company is preparing to produce it on a commercial basis. The rapid expansion of shrimp farming throughout the Third World opens a large market for the product.

A new agriculture

The new agriculture described in the preceding pages will require fundamental changes in both North and South. For the North, it will mean shifting from an agriculture that exhausts the land in its need for ever-larger harvests to one that balances production and conservation and distribution and consumption. For the South, it means shifting emphasis from export crops to domestic supplies of staples, from commercial landowners to small farmers. If small farmers are to succeed, they need to be supported by credit and better prices, postharvest and

"By their fruits..."

The World Food Prize is the foremost international award recognizing outstanding individual achievements in improving the quality, quantity, or availability of food in the world. Conceived by Dr Norman E. Borlaug, 1970 recipient of the Nobel Peace Prize, it was sponsored in 1986 by the General Foods Fund, Inc. The prize emphasizes the importance of a nutritious and sustainable food supply for all people, and calls attention both to what has been accomplished and to what can be done in the future. Based in Des Moines, Iowa, the World Food Prize Foundation was established in 1990.

Significantly, the work accomplished by the five laureates to date was carried out in developing countries. Four of the laureates have contributed to increasing food supplies in developing countries. The most recent award recognizes achievements in the area of nutrition.

- 1987 Dr M.S. Swaminathan, former secretary of agriculture for India and architect of India's Green Revolution, which led to India's grain self-sufficiency.
- 1988 Dr Robert F. Chandler, Jr, founding director of the International Rice Research Institute (IRRI) in Los Baños, Philippines, where high-yielding rice varieties were developed.
- 1989 Dr Verghese Kurien, chairman of India's National Dairy Development Board and founder of "Operation Flood," which linked India's milksheds into cooperatives that now market milk in 500 cities and towns.
- 1990 Dr John S. Niederhauser of the United States, for leadership in advancing the production and consumption of the potato.
- 1991 Dr Nevin S. Scrimshaw, public health doctor and international nutritionist for his outstanding contributions in the fight against hunger and malnutrition.

market facilities, appropriate research, secure land tenure, and access to good land.

The CGIAR system of agricultural research centres is responding to the need for change. In the most recent review of its priorities and strategies by its Technical Advisory Committee, its goal was broadened to incorporate the concept of achieving food self-reliance, through the combination of imports to supplement national products, in the developing world. Its earlier goal spoke of food self-sufficiency, i.e., a country produces enough food to feed its population and does not depend on imports.

More than mere semantics, the change has major implications. In particular, it means that the CGIAR will focus on employment- and income-generating opportunities in addition to production issues. The CGIAR previously restricted its support to food crops only. It also means that research by CGIAR ought to reinforce the comparative advantage that countries and regions have in the supply of agricultural,

forestry, and fisheries products and rely on markets and trade to satisfy the basic food and nutritional needs of low-income people.

International research efforts will continue to place a premium on those products that improve the nutrition and well-being of the poor, on regions where production increases are most urgent if the regions are to become self-reliant by 2010, on regions with the greatest potential for increasing productivity, on small countries with weaker national research systems, and on those regions where there are no alternative sources of research.

A convergence of interests

The progress that has been made in increasing world food supplies is a tribute to what can be achieved through cooperation and collective effort. An example of that cooperation is the CGIAR network of international agricultural research centres (IARCs) that is working to transform agriculture in the tropics and bring about a better future for subsistence farmers and their families.

The growth of the centres has also been instrumental in training a cadre of scientists to lead the research. There are now sufficient numbers of trained agricultural researchers in Sub-Saharan Africa, and enough financial aid from the North, to tackle agricultural problems. As the scientific capacity of the developing nations increases, the South will become an equal partner in the quest to assure tomorrow's food supplies.

The network of IARCs, which also includes some non-CGIAR centres, has already had a salutary effect on world research direction by breaking the monopoly of the North on the most valuable resource: knowledge. As William R. Furtick, former director for Food and Agriculture, US Agency for International Development, told directors of international agricultural programs at US universities in 1989: "Agricultural research outside the US has burst forth over the past few years and broken the US monopoly on high technology agriculture." As a result of the huge global system that has developed, even the US has become a net importer of new agricultural technology.

But given the globalization of world food sources and the need for greater cohesiveness to face an uncertain future, it may be counterproductive to speak of "imports" or "exports" of knowledge. Global efforts will be needed not only to increase food production but to improve the postharvest handling, processing, and distribution of foods. Innovations and insights must be encouraged that help raise agricultural productivity, increase the efficiency of processing and marketing systems, add value to agricultural products, and increase the nutritional value of the diet. These must flow unhindered between researchers and farmers, between North and South. Knowledge knows no borders.

Nor should food. The North profited greatly from crops imported from the South in ancient — and more recent — times. The South has benefited greatly from the North's experience in raising production by conventional means. The North stands to benefit equally from new techniques for managing agricultural resources perfected in the less-productive areas of the South.

As this document has described, whether feeding the world's population in the 1990s and beyond is a challenge or a crisis depends on actions taken now:

- Actions to redress an inequitable world trade system.
- Actions to preserve the genetic diversity of the planet so that we are better able to adapt our food sources to changing conditions.
- Actions to preserve the productive natural base of the planet.
- Actions to support the efforts of developing-country researchers and governments who are striving to place their agriculture on a productive, yet sustainable, basis.

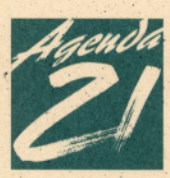
It is a task that will require everyone's effort.

About the Reviewers

The principal IDRC reviewer and resource person for this publication was Richard Young, Nutrition Coordinator; with the collaboration of Brian Belcher, Research Officer, Agriculture Food and Nutrition Sciences; Gilles Forget, Acting Director, Health Sciences; and Joachim Voss, Program Director, Sustainable Production Systems, Environment and Natural Resources Division.

Written and researched on behalf of the Public Information Program, IDRC by Michelle Hibler, an Ottawa-based freelance journalist.

The *Searching Series* is intended for an informed public concerned with the broad questions of international development. The opinions expressed are meant to inform and encourage interest in the issues related to research and development. In an effort to understand our developing world better, *Searching* examines the common challenges that face both North and South.



Sustainable
and Equitable
Development

Searching Series 4